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Electrical and Electronic Equipment Maintenance Management System Wadi Al-Abiad Mine – JPMC

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List of Abbreviations

Abbreviation	Meaning
ABB	Asia Brown Bovery
AC	Alternating Current
AFSR	Authorization for Stock Requirements
AOH	Annual Operating Hours
BBC	Brown Bovery Company
BS 60529	British Standard 60529
CBM	Condition Based Maintenance.
CFL	Compact Fluorescent Lamp.
Cm	Maintenance Cost
CMMS	Computerized Maintenance Management System
CO2	Carbon di oxide
Cp	Production Losses Cost
Csp	Cost Of Spare Parts
CV	Variable Cost Per Hour
DCS	Distributed Control System.
DMAIC	Define- Measure- Analyze- Improve- Control.
DOE	Department Of Energy
DSS	Decision Support System
D-STATCOM	Distribution Static Compensator
DT	Down Time
EASA	Electrical Apparatus Service Association
ECM	Energy Consumed by old motors
EC	Efficiency of old motor
ECS	Energy Cost Saving
EDS	Electrical Demand Saving
EDCS	Annual Demand Cost Savings
EEM	Energy Efficient Motor
EISA	Energy Independence And Security Act
EP	Efficiency of proposed motor
EPM	Electrical Preventive Maintenance
ES	Energy Saving
E-MAIL	Electronic Mail
FMEA	Failure Mode Effect Analysis
IP	Ingress Protection
JD	Jordan Dinar
JIT	Just In Time
JPMC	Jordan Phosphate Mines Company.
KM	Kilo Meter
KVA	Kilo Volt Ampere
KV	Kilo Volt
KW	Kilo Watt

KWH	Kilo Watt Hour
LED	Light Emitting Diode
MTBF	Mean Time Between Failures
MTTR	Mean Time To Repair
NASA	National Aeronautics and Space Administration
NEMA	National Electrical Manufacturers Association
NFPA 70B	National Fire Protection Association 70B
NEPCO	National Electric Power Company
NETA	National Electrical Testing Association
PdM	Predictive Maintenance.
PF	Power Factor
PLC	Programmable Logic Controller
Plos	Production Loss In Unit Per Hour
PM	Preventive Maintenance
RCM	Reliability Centered Maintenance
RPM	Revolution Per Minute
SF	Sharing Factor of electric consumption
Sprice	Selling Price
TPM	Total Productive Maintenance.
TQM	Total Quality Management.
VSD	Variable Speed Drive
UPS	Uninterruptible Power Supply

Abstract

Electrical And Electronic Equipment Maintenance Management System Wadi Al-Abiad Mine (JPMC)

Hashem Salem AL- Lawanseh
Mutah University, 2016

Maintenance management links the technical and management sides of maintenance which helps maintenance managers and industrial facilities managers to take important decisions that significantly contribute in cutting maintenance costs and overall production costs as a consequence. Electrical and electronic equipments maintenance management is an important field to create opportunities to reduce maintenance costs at the same time of achieving better efficiency and reliability. Following maintenance management procedures that deviate from the best practices and the international standards might cause weak maintenance performance and significant finance losses, such deviations are poor documentation and non availability of preventive maintenance procedures for the electrical and electronic equipments.

This is a field analyzing study of the current electrical and electronic maintenance in AL-Abiad mine in comparison to the best practices and the international standards. The results show shortage in preventive maintenance activities and high reliance on corrective maintenance, oral communication in maintenance management procedures instead of using paper or computer, documentation absence. The study also includes distributing a questionnaire on the mine maintenance and operation personnel, the results have shown that following maintenance procedures as per the best practices and the international standards, using computer do not significantly affect maintenance costs.

Suggesting alternative equipments, systems, and practices can save 928135 JD annual costs, these suggestions include: using variable speed controllers (VSD) for 5, 90 kw motors, resizing motors to the suitable original design, adopting preventive maintenance for the electrical and electronic equipments, replacing the current lighting system with new controlled and energy saving technology, addressing electric power quality and continuity, fixing capacitors for power factor correction, connecting temperature protection sensors on large motors, good selection of electric equipments specifications such as ingress protection (IP) to withstand the operational and environmental conditions, replacing selected motors by more efficient ones, connecting new power line insulators, spare parts inventory control.

Preventive maintenance software has been built to help in maintenance activities scheduling, documentation, and reminding with the maintenance dates. Preventive maintenance procedures have been prepared for electric equipments as per the international standards and the manufacturer recommendations to be followed by the maintenance personnel.

الملخص

نظام إدارة صيانة المعدات الكهربائية والإلكترونية
منجم الوادي الأبيض (شركة مناجم الفوسفات)
هاشم سالم اللوانسة
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إدارة الصيانة تربط بين الجانب الإداري والجانب الفني في مجال الصيانة مما يساعد المدراء على مستوى الصيانة وإدارة المنشآت الصناعية في اتخاذ قرارات تساهم في تخفيض تكلفة الصيانة وتقليل التكلفة الكلية للإنتاج. وإدارة صيانة المعدات الكهربائية هي واحدة من الجوانب المهمة التي يمكن من خلالها إحداث فرص حقيقية في تخفيض تكلفة الصيانة بالتزامن مع تحقيق الفعالية والآداء الأفضل. إن عدم اتباع اجراءات إدارة الصيانة حسب أفضل الممارسات والمعايير الدولية مثل غياب التوثيق وعدم توفر اجراءات صيانة وقائية للمعدات الكهربائية يمكن أن يتسبب في ضعف أداء الصيانة وتكبد خسائر كبيرة.

هذه الدراسة هي نتاج تحليل لواقع نظام الصيانة الخاص بالمعدات الكهربائية في منجم الوادي الأبيض مقارنة مع أفضل الممارسات في مجال الصيانة وكذلك المعايير الدولية.نتائج الدراسة أظهرت أن هنالك نقص واضح في اتباع الصيانة الوقائية واعتماد كبير على الصيانة الإصلاحية بعد تعطل المعدة وكذلك الإعتماد على التواصل الشفوي في إجراءات الصيانة بدلاً من استخدام الورق أو الحاسوب وغياب التوثيق إلى حد كبير.كما اشتملت الدراسة على توزيع استبيان على أفراد الصيانة والتشغيل في منجم الوادي الأبيض وأظهرت نتائج الإستبيان أن اتباع الصيانة الحالي للإجراءات حسب الممارسات الفضلى والمعايير الدولية ومدى استخدام الحاسوب في الصيانة لم يؤثر بشكل كبير في تقليل كلفة الصيانة .

تم اقتراح العديد من البدائل للمعدات وممارسات الصيانة والتي من خلالها يتم تحقيق وفر في التكاليف السنوية وبمقدار928135 دينار، هذه المقترحات تشمل: استخدام أجهزة التحكم بسرعة المحركات الحثية، تركيب محركات بالحجم التصميمي الأنسب، تبني سياسة الصيانة الوقائية للمعدات الكهربائية، استبدال أنظمة الإنارة القديمة بتكنولوجيا حديثة موفرة للطاقة، معالجة جودة واستمرارية الطاقة الكهربائية، تصحيح معامل القدرة في شبكة كهرباء المنجم، توصيل أجهزة تحكم وقياس مثل حساسات الحماية الحرارية على المحركات الكبيرة، اختيار مواصفات المعدات الكهربائية لتتحمل الظروف التشغيلية والبيئية في المنجم مثل الغبار والماء،استبدال المحركات بمحركات عالية الفعالية، استبدال عوازل خطوط نقل الكهرباء بعوازل ذات مواصفات أفضل، المراقبة والتحكم برصيد قطع الغيار.

تم تصميم وبناء برمجية خاصة بالجدولة الزمنية والتوثيق والتذكير بمواعيد الصيانة الوقائية لمعدات المنجم كنموذج ريادي لاستخدام نظام إدارة الصيانة المحوسب (CMMS) في المستقبل. كذلك تم إعداد إجراءات الصيانة الوقائية للمعدات الكهربائية في المنجم حسب المعايير العالمية وتوصيات الشركات الصانعة ليتم اتباعها من قبل أفراد الصيانة.

Chapter one
Introduction

1.1Over View

"Although impressive progress has been made in maintaining equipment in the field in an effective manner, maintenance of equipment is still a challenge due to factors such as size, cost, complexity, and competition"(Dhillon, 2002, p.13). The increasing competition in the market is behind companies searching for new ways to support their position as a competitive manufacturer (Alsyouf, 2004).

Earlier, Maintenance has accounted as cost center and considered as "necessary evil" or ''nothing can be done to improve maintenance costs" which was the general opinion years a go as Mobley (2004) said. As maintenance cost contributed significantly in the production costs, the need to reduce these costs followed by the related studies and researches have impacts on converting maintenance from cost center to be an investment center. Nevertheless, plenty of facilities still a way from this understanding of maintenance as a way to reduce the production costs and still following traditional maintenance practices and relying on the idea of fixing the problem only in case of equipment failure with the tremendous related costs.

1.2 Importance Of Maintenance

Maintenance is set of activities that are performed to protect and keep machinery at standard extent with reasonable cost and increase the useful life and avoid the sudden failure, this will increase the reliability and availability (Masoumi, 2013). In other words, the goal of maintenance is seeking to keep equipments running healthy in the best operational conditions with the least acquired costs.

"An event may present an immediate environmental, performance, or safety implication. Thus, there is a definite need for effective asset management and maintenance practices that will positively influence critical success factors such as safety, product quality, speed of innovation, price, profitability, and reliable delivery" (Dhillon, 2002, p.13).

About 80% of the industry investment is spent to correct chronic failures of machines, systems, and people, the elimination of many of these chronic failures through effective maintenance can reduce the cost near 60% (Dhillon, 2002). Evaluations indicate that on average, one third of all maintenance costs are wasted through ineffective maintenance management methods, this incredible level of inefficiency cannot be absorbed by different industries and hope to compete in the world market fades a way (Mobley, 2004).

1.3 Electric equipment management

If compared to other equipments, electric asset management has an added opportunity to increase efficiency and reduce production costs by benefiting from the fast and increasing development in electronics, control and measurement instrumentations and the integration of power consuming equipments with electronic based devices, which could increase efficiency and reduce energy consumption. Also, electric equipments may give indications before breakdown or failure; these indications are continuously monitored or periodically measured which may prevent complete failures.

1.4 Maintenance management

Maintenance management is the crucial factor in maximizing the facility asset value in terms of productivity, reliability and cost. Maintenance Management deals with planning, organizing and controlling, and improving maintenance activities, it requires keeping an asset performing as per the standard that is required by the facility.

1.5 Back ground of the study

The back ground of this research is to study the electrical department maintenance system and its management in AL-Abiad Mine (JPMC), which is one of the biggest manufacturing and mining companies in Jordan, and suggest what improvements can be implemented to build an effective maintenance management system.

1.6 Statement of the problem

Many organizations are looking for achieving the target final product and profit, keeping high quality, system reliability and customer satisfaction with the minimum cost to stay in competition**.**

Total quality management states that every department has its role to achieve the organization goals, equipment effective maintenance is one of the most important processes in the organization, and maintenance management concerns the planning and scheduling activities and resources.

Selecting suitable maintenance policies as (preventive, corrective, predictive, or mix of them) is a key to reduce maintenance overall costs, increase machines availability and decrease failures and stopping times.

Maintenance policies and identifying the items or equipments that should be concerned to be predictive or preventive maintenance listed or left for reactive maintenance policy is a good practice.

The problem of this study can be summarized by:

-The amount of maintenance practices in the mine and how much they deviate from the best practices and international standards?

- Specifying the level of the current maintenance management practices as per the international standards and the use of computer in achieving the mine goals such as reducing maintenance costs.
- Specifying the impact of an effective electric equipment maintenance management on the targeted organization.
- Preparing a computerized maintenance management system model and implement it.
- Implement a more cost effective maintenance practices.
- How much effects are these cost effective practices have in maintenance cost reduction?
- Testing the hypothesis "It is assumed that there is no reduction in maintenance cost based on the present weak use of international maintenance standards in Al -Abiad Mine".
- Testing the hypothesis "It is assumed that the present use of computer techniques at the present time in AL- Abiad Mine is the cause of non reduced maintenance cost".

1.7 Importance of the study

The importance of the study and its contribution to the industrial sector and the literature:

1. This study suggests implementing some of solutions, alternatives and practices. These suggestions are actually started to be implemented.
2. It is a study that can be used and applied at other organizations.
3. The study highlights the importance of maintenance and maintenance management in manufacturing organization to reduce maintenance and production costs.
4. The study will seek the improvement of maintenance and make it less expensive.
5. It is a study that is conducted in a facility that suffers poor maintenance procedures.
6. It is a study that concerns building an effective maintenance management system in a manufacturing organization.

1.8 Objectives of the study

The main objectives of the study:

- Assess the current electric equipment maintenance management practices in Wadi AL-Abiad mine and detect the defects.
- Build an effective computerized maintenance management system used to activate and enhance maintenance activities.
- Find cost effective solutions and world class practices to eliminate the defects and wastes found during the study.
- find cost effective alternatives for the old, inefficient, energy consumer equipments.

- Investigating the role of engineering management in maintenance.

1.9 Methodology

A case study is selected, Jordan Phosphate Mines Company which consists chemical plants and mines, so it is a suitable case to have because of the role of maintenance in such harsh industries and maintenance need for more investment and development.

This case study will be conducted according to the following tools:

- SPSS is used to calculate the following: Descriptive Statistic Measures (Mean, Standard Deviation), Cronbach’s Alpha, Pearson Correlation Coefficient, Simple regression Analysis.
- A questionnaire
- Literature review of maintenance management resources.
- Field observations at the targeted case.
- Interview with maintenance team members.
- The organization records.
- Motor Master software.

Chapter Two
Literature Review

2.1 Maintenance Expressions And Definitions

"Maintenance is the routine and recurring process of keeping a particular machine or asset in its normal operating condition so that it can deliver its expected performance or service without causing any loss of time on account of breakdown"(Mishra, 2005, p.2).

Or it is "All actions appropriate for retaining an item/part/equipment in, or restoring it to, a given condition" (Dhillon, 2002, p.15).

Maintainability is the ability of equipment to meet operational objectives with a minimum expenditure of maintenance effort under operational environment conditions in which scheduled and unscheduled maintenance is performed ("Dictionary Of Engineering,"2003, p.342).

Maintenance Engineering can be thought of as "the activity of equipment/item maintenance that develops concepts, criteria, and technical requirements in conceptional and acquisition phases to be used and maintained in a current status during the operation phase to assure effective maintenance support of equipment." (Dhillon, 2002, p.15).

"Reliability is the probability that an item will perform its stated function satisfactorily for the desired period when used per the specified conditions" (Dhillon, 2002, p.15).

2.2 History of Maintenance

As craftsmen were the earliest manufacturers, they made their own tools (Smith & Hawkins, 2004), when these tools fail they used to maintain them by their own basic skills to keep them working. The event of John Keys invention of the flying shuttle for the textile industry in 1733 followed by the steam engine development by James Watt (1736-1819) in Great Britain which replaced human, animal or water power by machine and brought about production with interchangeable parts (Smith & Hawkins, 2004)**,** that event may be considered as the beginning of equipment maintenance engineering.

Since the industrial revolution, maintenance of equipment in an effective way witnessed an impressive progress; however maintenance of equipment is still a challenge because of factors like cost, size, complexity, and competition (Dhillon, 2002).

In recent years, the facility maintenance conception has been gradually changing from being as a support function for production process to ward being as an integral part of it, this change has caused by many factors such as the advent of automation, the need for mass production, production schedules, the capital equipment high cost and increased machine optimization (Clifton, 1987).

Since 1930s maintenance evolution has been timely classified into three generations according to Moubray (1997). Maintenance modern developments can be included in the forth generation as shown in Figure (2.1).

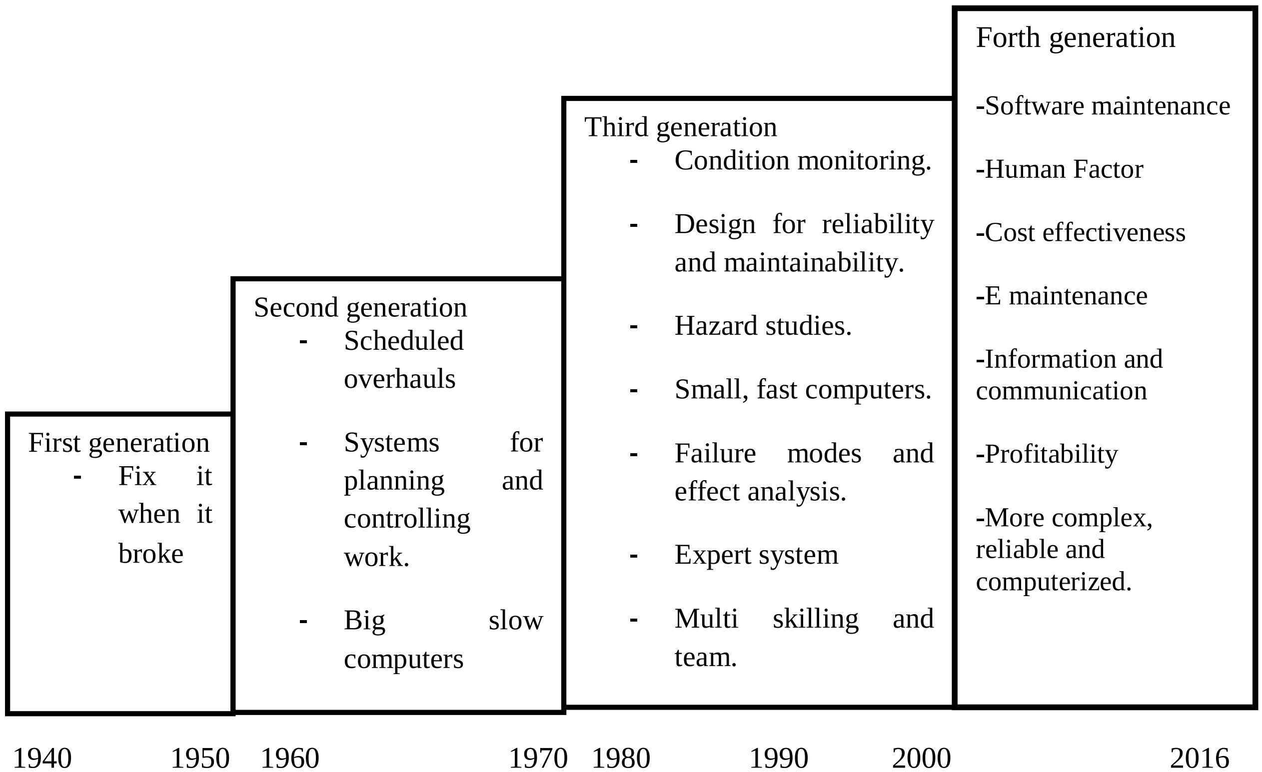

Figure 2.1

Changing maintenance techniques, Moubray (1997) modified by author where fourth generation is added.

Moubray (1997) summarized the developments at different maintenance fields during the three generations as follows:

2.2.1 The First Generation

The first generation spans the period up to the Second World War when the industry has no high level of mechanization, most of the equipments were simple or over – designed, reliable and easily repaired, as a result downtime has no high consequences, prevention of the failure has no high priority, there was no need for special skills and systematic

maintenance except simple servicing, cleaning and lubrication were done as needed (Moubray, 1997**)**. It was thought at earlier times of maintenance as an excess cost to the plant which did not add any value to the final product and traditionally maintenance was only done when it was impossible to run the plant (Kumar & Kapil, 2013).

2.2.2 The Second Generation

During the Second World War dramatic changes happened and initiated the maintenance second generation, this is due to manpower shortage and the increasing demand for production, This led to more mechanization and automation, by the 1950's industry become dependent on more complex machines, so focus on downtime increased and the idea of prevention of failures emerged, the concept of preventive maintenance that was mainly based on performing overhauls at a fixed intervals also emerged (Moubray, 1997).

Maintenance cost started to increase sharply relative to operating and failure prevention costs, this led to development of maintenance planning and control systems which helped in bringing maintenance under control, and are regarded as part of maintenance practice, When the cost of maintenance and the tied up capital increased the manufacturers tried to extend the assets lifetime at the time of enhancing maintenance planning and control systems (Moubray, 1997).

2.2.3 The Third Generation

The Third generation started at the mid of seventies, which was concerned with reducing the downtime while industry began using Just–in-time (JIT) systems where reduced stocks of works in progress mean that small failure may stops a whole plant, The growth of mechanization, automation, complexity means that availability, reliability and quality standards have become key issues at many industries, since Failures may have serious safety and environmental impacts, standards of both areas are rising quickly and the organizations conformity to the society safety and environment standards became a necessity, which adds an order of magnitude to the dependence on physical assets integrity and the effect of this on the organization survival over the cost, This resulted in a new approach of maintenance known as reliability centered maintenance (Moubrey, 1997). More advanced and faster computers encouraged The growth of using expert systems, advancements in Decision Support Systems (DSS) and Failure Mode Effect Analysis (FMEA) with the development of predictive maintenance tools have a significant role in maintenance policy selection (Hogan, Hardiman, & Naughton, 2011). Technical advancements led to more complex systems along with the

development of computerized management system (CMMS) (Elisson, 2013).

2.3 The Coming Forth Generation

During the 21st century it is expected that equipment of this century will be more complex, reliable, and more computerized, which will increase the importance of software maintenance, also more concern on maintenance with respect to such issues as the human factor, quality, safety, and cost effectiveness will be one of the most attributes of maintenance (Dhillon, 2002). Within the era of e-manufacturing and e-business, e- maintenance which refers to the integration of information and communication gives the opportunity for new generation of maintenance, by integrating the existing telemaintenance principles with web-service and modern e-collaboration principles, a lot of benefits emerge such as: sharing and exchanging information, knowledge and e-intelligence, these benefits may include taking remote maintenance actions such as: setup, configuration, diagnosis and debugging (Marquez & Iung, 2008).

"New thinking and new strategies will be required to realize potential benefits and turn them into profitability. All in all, profitable operations will be the ones that have employed modern thinking to evolve an equipment management strategy that takes effective advantage of new information, technology, and methods" (Dhillon, 2002, p.3).

2.4 Electrical Equipment Maintenance

Electricity is providing energy to perform wide range of operations and functions, electrical equipment is almost has high initial installations or replacement cost but it is significantly has higher cost in the case of unscheduled breakdown, in order to reduce the relative breakdown incurred cost and financially survive, facilities perform adequate maintenance plan for its expensive electrical equipment to be more cost effective, reliable, safely operate for a relatively long life, this plan must identify the different types of equipment to be serviced, and address these equipment operating and environmental conditions and maintenance needs (Lewis, 1999).

2.5 Maintenance Types:

There is a big argument about defining the concept of maintenance, Wireman (1984) indicates that maintenance can be broken into four main classifications: breakdown, corrective, renovative, and preventive with two forms monitored and scheduled. Mobley, Higgins and Wikoff (2008) decided that industrial facilities utilize two main types of maintenance management: Run-to-Failure, or preventive maintenance. On the other hand maintenance can be divided into reactive maintenance, preventive maintenance, and predictive maintenance (Sullivan, Pugh, Melendez, &

Hunt, 2010). Also maintenance strategies may be classified into three categories: breakdown, preventive, and condition- based maintenance (Ben- Daya, Duffuaa, & Raouf, 2000).

Maintenance types can be presented in this study as shown in the model of figure (2.2) and based on the European Standard 13306 (EN 13306, 2001); this model divides maintenance mainly into two sections as corrective maintenance or as preventive maintenance.

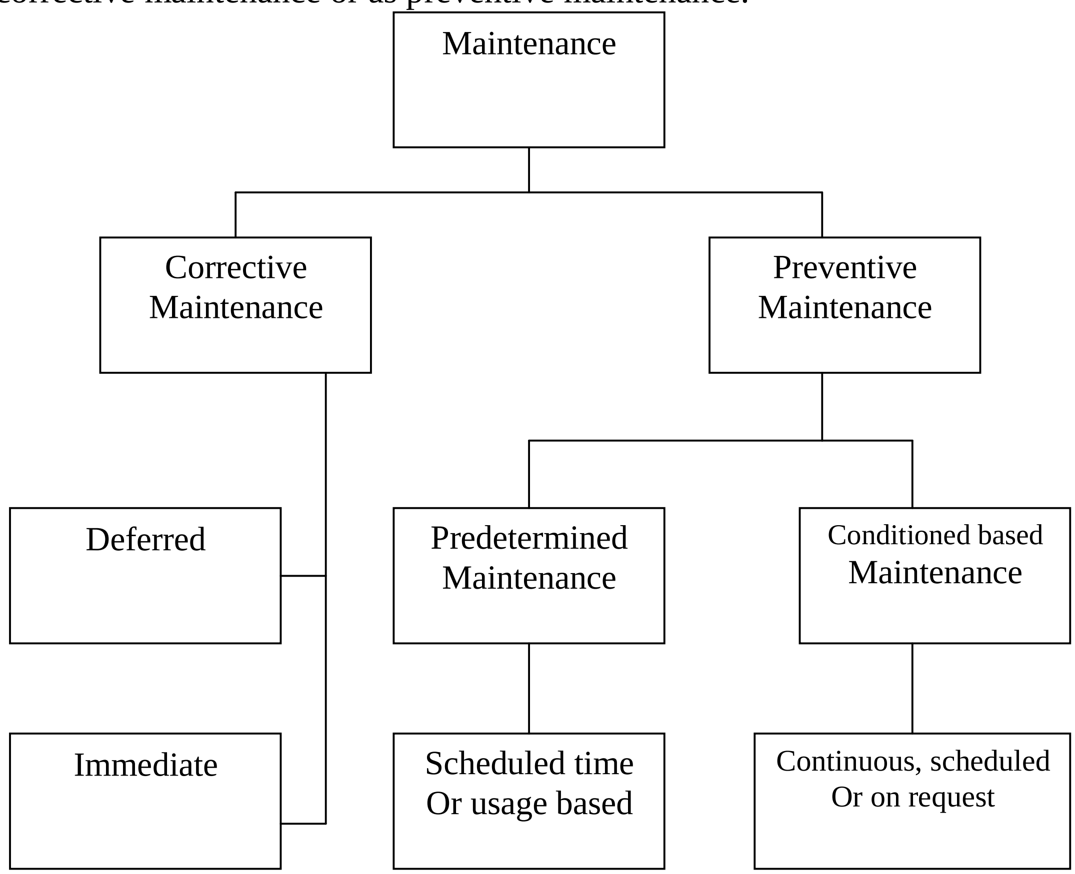

Figure 2.2
Overall view of maintenance as presented in the EN 13306: 2001 standard.

2.5.1 Corrective Maintenance

Corrective maintenance is defined as “maintenance carried out after fault recognition and intended to put an item into a state in which it can perform a required function”. British Standard Institute (BS EN 13306, 2001).

Corrective maintenance is the unscheduled maintenance/repair, activities to return items/equipment back to a defined state and carried out because maintenance personnel or users perceived defects or failures (Dhillon, 2002).

Corrective maintenance can be also addressed as maintenance job that may be performed by repairing or replacing components to restore an equipment after failure or after inability to take its full capacity because of worn- out component to operate as per the accepted standard, if properly carried out, the corrective maintenance will reduce the equipment downtime and bring down the maintenance costs (Mishra, 2005).

Corrective maintenance can be divided into two parts: deferred and immediate, where deferred maintenance is not carried out immediately after recognizing a fault as they are classified to be non-critical while immediate requires prompt response, this approach is used to prioritize maintenance activities (International Atomic Energy Agency (IAEA), 2007).

2.5.2 Preventive Maintenance PM

Takes an action to keep an equipment which is in operation state in an operating condition by means of inspection, detection, and failure prevention (Wireman, 1984).

Preventive maintenance can be subdivided as either (C.B maintenance) or pre-determined maintenance, which offer the lead time to efficiently carrying out maintenance (Levitt, 2003). Predetermined or periodic maintenance is always performed according to intervals based on calendar time, or numbers of units of use, these intervals are established based on the manufacturers' recommendations or by experience (IAEA, 2007). According to IAEA (2007), the equipment list covered by preventive maintenance is established during the plant startup stage and is modified as experience accumulates; factors that might be accounted for preparing the equipment list, the associated maintenance tasks, and their frequency of performance include:

1. Importance of equipment failure to the overall plant function.
2. Equipment duty cycles.
3. Equipment redundancies.
4. Effectiveness of the maintenance activities in preventing failures.

Sullivan et al. (2010) added another factor which corresponds to the:

5. Effectiveness of the maintenances activities in predicting failures.

According to Sullivan et al. (2010), advantages and disadvantages of PM are:

1. Cost effective in many capital – intensive process:
2. Flexibility allows for the adjustment of maintenance periodicity.
3. Increased component life cycle.
4. Energy savings.
5. Reduced equipment or process failure.
6. Estimated 12% to 18% cost saving over reactive maintenance program.

Disadvantage of PM:

1. Catastrophic failures still likely to occur.
2. Labor intensive.
3. Includes performance of unneeded maintenance.
4. Potential for incidental damage to components in conducting unneeded maintenance.

2.5.2.1 Time Based Or Scheduled PM

A time based maintenance method is one of the PM forms in which the maintenance activities are planned and scheduled based on predetermined intervals to keep and enhance equipment performance and reliability by preventing failure of equipment before it occurs by such actions as replacing worn or defected components (Borikar, Shingare, Sarnaik, & Bhusari, 2014), servicing, lubrication, cleaning, calibration or stopping for more corrective maintenance. The scheduling process can be performed by a computer system, human memory, wall charts or other scheduling ways (Borikar et al., 2014). Time based, scheduled, or fixed-interval PM tasks may be used if there is opportunity to reduce failures that cannot be detected beforehand or if dictated by production conditions (Mobley, 2004).

The period between P.M tasks is termed as periodicity, According to Wireman (1984)**,** there are recommended techniques for setting initial periodicity:

1. Periodicity will vary with the equipment age, bathtub curve explains that PM should be performed more frequently at the first and third phases of the equipment age, this frequency should be modified a long the equipment life cycle.
2. Failure statistical analysis is also used as a basis for selecting periodicities, the distribution and probability of failure should be known.
3. If it was difficult to determine the period between PM events, it is possible to consult an engineering consultant working in this field to establish the correct period.

The manufacturers' recommendations are also thought to be a good source for setting periodicity, especially if the equipment operating conditions comply with the standard conditions equipment designed for. Equipment failure documented history and the experience of the employees may be also used to anticipate periods between PM activities.

2.5.2.2 Predictive Maintenance PdM

Predictive maintenance PdM or Condition based maintenance CBM is an approach based on monitoring or measuring the equipment conditions or performance, it is the maintenance type that carried out in response to

critical deterioration in equipment as indicated by the change of that equipment monitored parameters (Mishra, 2005). By monitoring, Inspection or testing the equipment conditions an early indication of random failure can be detected while equipment continues its operation even unfavorable condition giving the opportunity for corrective action before the equipment breakdown and avoiding costly maintenance that may include cost of replacement. This monitoring can be periodically scheduled, or as required or continuously by sensors connected to the process control systems such as PLC and DCS.

Predictive maintenance requires training for personnel who perform monitoring and analysis of measurements as a result of sophisticated technology tools and software used to predict repair cycles, capital cost of purchasing PdM tools and the training of personnel is high compared to other types of maintenance. Although it needs fewer men – hours and parts compared to other maintenance types, experts and vendors recommended that PdM technology should not be purchased for in-house use without proper personnel training and good implementation (Sullivan et al, 2010). Otherwise organizations are advised to outsource PdM service with outside vendor and depending on his equipment and experience.

By using (CBM)/PdM technology and tools to measure and analyze equipment conditions and indicators, the need for maintenance and the most probable time of failure can be determined, optimizing the equipment reliability and availability, enhancing the facility depending on and acting in a proactive manner, applying CBM allows the lowest cost and most effective maintenance plan by determining the correct maintenance activity at the correct time (IAEA, 2007).

The primary objectives of an optimized maintenance strategy programmer that include predictive and condition based maintenance are given by IAEA (2007), which include:

1. Improve availability
    1. Reduced forced outages.
    2. Improve reliability.
2. Enhance equipment life
    1. Reduce wear from frequent rebuilding.
    2. Minimize potential for problems in disassembly and reassembly.
    3. Detect problems as they occur.
3. Save maintenance costs
    1. Reduce repair costs.
    2. Reduce overtime.
    3. Reduce parts inventory requirements.

According to Mobley (1990) a comprehensive condition based maintenance strategy must include a lot of monitoring and diagnostic techniques, these technologies include:

1. Vibration monitoring.
2. Thermography.
3. Tribology.
4. Process parameter.
5. Visual inspections.
6. Other nondestructive testing techniques.

Because Electrical faults are seldom visible, costly, and have safety concerns, there are various technologies that can be used to monitor important electrical parameters providing useful information about the impending faults such as phase imbalance, insulation breakdown, and high resistance connections ; these technologies are listed in table 2.1 (Dhillon, 2002).

Table 2.1
Electrical Condition Monitoring Technologies

Technology name	electrical equipment
Surge testing	motor
Motor circuit analysis	motor
Radio frequency monitoring	generator
Infrared thermography	electric contacts
Motor current spectrum analysis	motor
Airborne ultasonics	electrical switchgear, cabling
Megohmmeter testing	generator, motor, cabling
Turns ratio	transformer
Transformer oil analysis	transformer
High potential testing	motors, electrical cabling
Time domain reflectometry	cabling
Starting current readings	motor
Power factor and harmonic distortion	transformer
Conductor complex impedance	motors

2.6 Maintenance Management Philosophies

2.6.1 Total Productive Maintenance (TPM)

TPM is keeping the current plant and equipment at its highest productive level through cooperation of all areas of the organization by breaking down the traditional barriers between maintenance and production personnel so they are working together without regard to organizational structure, using their skills and experience, trying to achieve the common objectives – high performance or total productivity and creating a system in which all maintenance activities can be planned and performed without

interference with the production process or plan. (D. Besterfield, Michna, G. Besterfield, Sacre, 2003). TPM process involves everyone in the facility, from top level management to production labors, and production support groups to outside suppliers, top management support and work teams activities are necessary to achieve the continuous incremental improvements towards the equipment availability and degradation prevention (Mobley et al., 2008).

TPM does not mean that maintenance techniques such as predictive and preventive are not used, they are essential for a successful TPM environment, the point is that total maintenance function should be directed towards the elimination of unplanned maintenance and preventing surprise equipment breakdown (D. Besterfield et al., 2003), in TPM, maintenance is recognized as a valuable resource which has a role in making the business more profitable and the industrial system more competitive by continuously improving the equipment capability, as well as making the practice of maintenance more efficient (Mobley et al., 2008).

2.6.2 Reliability Centered Maintenance (RCM)

"RCM is a process used to determine what must be done to ensure that any physical asset continues to do whatever its users want it do in its present operating context" (Moubray, 1997, p.7). Or it is a process aims to ensure that the physical facility is continuously able to meet its designed functions in its current operating context (Dhillon, 2002)

According to Moubray (1997) the RCM process about any asset or system includes answering the following seven questions:

1. What are the function and performance of the interested asset in its operating conditions?
2. In what ways this asset fails to accomplish its function?
3. What causes the functional failures?
4. What are the effects of each failure?
5. What are the consequences of each effect?
6. What are the actions that can prevent or predict each failure?
7. What are the procedures if no prevention activity is suitable?

"RCM is a systematic approach used to evaluate a facility's equipment and resources to best mate the two and result in high degree of facility reliability and cost effectiveness. RCM is a highly reliant on predictive maintenance but also recognizes that maintenance activities on equipment that is inexpensive and unimportant to facility reliability may best be left to a reactive maintenance approach" (Sullivan et al., 2010, p.5.5).

RCM is providing simple, easy and precise criteria for deciding the technically feasible proactive task in any context, deciding how often it

should be done and who should do it, RCM concerns task selection process for hidden failures (Moubray, 1997).

Applying RCM may achieve greater safety and environmental integrity, improved operation and production quality, more cost effective maintenance, longer life of expensive equipment, comprehensive documented database, greater employees' motivation and teamwork culture (Moubray, 1997).

2.6.3 Lean Maintenance

Lean Maintenance is a relatively new term, formed in the nineteenths of the last century, Lean Maintenance—emerging from Lean Manufacturing—adds some new techniques to TPM concepts to provide a more structured implementation process, Lean attempts to eliminate all forms of waste in the manufacturing process—including waste in the maintenance operation and activities (Smith & Hawking, 2004).

Smith and Hawking (2004) indicate that total productive maintenance forms the foundation of lean maintenance; also they find that it is difficult to implement lean maintenance without such a foundation. Planning and scheduling, documentation, work order system, computerized maintenance management system (CMMS), predictive maintenance, and the root cause failure analysis, represent the other maintenance bricks as shown in figure 2.3.

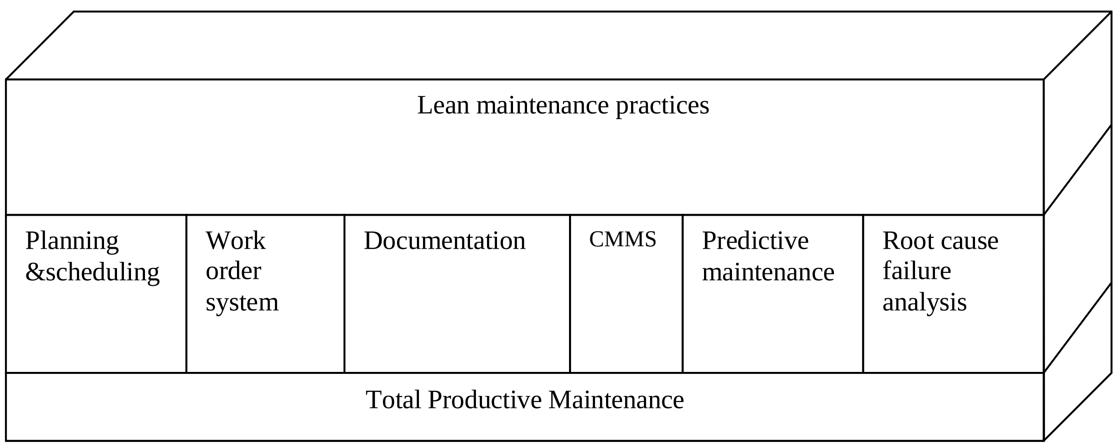

Figure 2.3
Lean maintenance practices as visualized by smith and Hawkins (2004)

Smith and Hawkins (2004) indicate that there are four important aspects of lean manufacturing concepts according to the American manufacturers view:

1. Waste Elimination
2. Standardized work practices
3. Just- in- time system

4. Doing it right the first time (quality control)

The Japanese expanded and added more concepts, including:

1. Integrated supply chain (From JIT)
2. Enhanced customers value (form quality control)
3. Value creating organization.
4. Committed management.
5. Winning employee commitment/ empowering employees.
6. Optimized equipment reliability.
7. Measurement (lean performance) system.
8. Plant –wide lines of communication.
9. Making and sustaining cultural change.

Kaizen

It is a Japanese word and philosophy that describes the management role in encouraging continuous improvements in small increments at no or little cost to make more efficient, effective, controlled and adaptable process (D. Besterfield et al., 2003). It is a process which means continuous improvement by application of kaizen (or lean) tools to individual, small scale, weekly limited projects within the overall facility. (Smith & Hawking, 2004).

According to D. Besterfield et al. (2003), the Kaizen improvement may focuses on the use of the following :

A. Value-added and non value-added work activities.
B. *Muda*, which refers to the elimination of the seven deadly wastes – over production, delay, transportation, processing, inventory, wasted motion, and defective parts.
C. Principles of motion study and the use of cell technology.
D. Materials handling and use of one piece flow.
E. Standard operating procedures documentation.
F. The 5-S process for organizing workplace which refer to 5 Japanese words that mean Sort (remove unnecessary item, separate), Straighten (organize, store, put in place), Scrub (clean the work place, shine), standardize (standard routine to sort, straighten and scrub), Spread (expand the process to other areas, sustain).
G. Better communication by using visual management and visual displays.
H. Use of Just-in-time principle (JIT) to supply or produce units in the right quantities, at the right time, and with the right resources.
I. *Poka-yoka* principle for detecting and preventing mistakes.
J. Team dynamics such as: conflict resolution, problem solving and communication skills.

2.6.4 Six Sigma Method

"Six Sigma is a problem – solving methodology that reduces costs by greatly reducing waste in all the processes involved in the creation and delivery of products." (Brue, 2006, p.5). "Sigma, σ, is a Greek alphabet, used statistically to measure the standard deviation i.e., variability in any process when in business, it is an indication of defects in the outputs of a process and how far these outputs deviate from perfection." (Zafar, Nazir, & Abbas, 2014, p.182).

Six sigma is a TQM process which uses process capability analysis to measure progress, sigma or σ, is the symbol of standard deviation, and it is the best measurement of process variability, the smaller the deviation value, the less variability in the measured process, at $\pm 6\sigma$ that represent the upper and lower specification limits of the process normal distribution curve, 99.9999998% of the product or service will be in conformance and between specifications. (D. Besterfield et al.). If six sigma methodologies are applied to equipment service, performance of maintenance and production will be improved, It is known that maintenance consumes significant part of the facilities budget, to stop thoughts of maintenance as a cost centre, to consider it as viable investment and to improve the quality of maintenance process in terms of financial benefits, the concept of six sigma is used.

According to Pyzdek (2003), six sigma projects address problems and achieve improvements using the following five – step process known as "DMAIC":

1. Define the goals of the improvement activity.
2. Measure the existing system.
3. Analyze the system to identify ways to eliminate the gap between the current performance of the system and the desired goals.
4. Improve the system by finding new ways to do things better, cheaper, or faster.
5. Control the new system to ensure that any deviations from the target are corrected and defects do not recur.

2.7 Computerized Maintenance Management System CMMS

2.7.1 What is a CMMS?

A CMMS is software that can track, schedule, and organize facility maintenance activities, it may include equipment history and inventory, work and purchase orders can be generated (Throop & Ward, 2000). A CMMS does not make decisions; rather it provides the maintenance manager with the information, reports, and indicators to affect the operational efficiency of a facility (Sullivan et al., 2004), a CMMS has the capability to track the details of day-to-day facility management (Throop & Ward, 2000).

CMMS may include a series of computer programs designed to present significant information to manage the huge load of maintenance data, stock control and purchase (Moballeghi, Makvandi, Abadshapouri, Ghaseminejad, & Kalantari, 2013)**.** By using CMMS detailed work orders can be generated containing the safety precautions and the special tools for that maintenance job (Throop & Ward, 2000).

2.7.2 Why use a CMMS?

The complexity of business operations such as maintenance is now such that it is in data or information, so, the ownership of the latest automation and information systems technologies consistently appeared in the first for achieving business vision for the best performing companies that make effective use of computers in supporting its high quality production processes (Kelly, 1998). The necessity of CMMS existence emerges because of the growing price of the raw material and human resources, and the increasing competition between manufacturers and producers (Throop & Ward, 2000).When the maintenance works costs is nearly 40% of the overall cost of production, it sounds that any actions can increase efficiency on the matter will reduce the costs and increase the facility competitiveness (Moballeghi et al., 2013). Beside the ability of a CMMS to keep track of maintenance activities history, to schedule the future maintenance jobs, it can provide the vendor and parts details and control the KPI (Kumar & Kapil, 2013).

Because CMMS components are computers and software, it can be installed on facility network to manage the maintenance works of different sections at the same facility.

2.7.3 Benefits of implementing a CMMS

According to Sullivan et al. (2004), Benefits in implementing a CMMS may include:

1. Detection of impending problems before a failure accrues resulting in fewer failures and customers complaints.
2. Achieving a higher level of planned maintenance activities that enables a more efficient use of staff resources.
3. Affecting inventory control enabling better spare parts forecasting to eliminate shortages and minimizes existing inventory.
4. Maintaining optimal equipment performance that reduces downtime and results in longer life.
5. One of the greatest benefits of using the CMMS is the elimination of paperwork and manual tracking of activities, thus enabling the maintenance staff to save time and become more productive, the functionality of CMMS lies in its ability to collect and store data and information that can be easily retrieved (Sullivan et al., 2004).

According to National Aeronautics and Space Administration (NASA, 2008)**,** other benefit is that:

6. Development of computerized maintenance management software (CMMS) has made it possible to determine the actual condition of equipment without relying on outdated techniques which refer the probability of failure to age and appearance instead of condition, also failure patterns and life –cycle cost can be determined by tracking and analyzing equipment history**.**

Moballeghi et al. (2013) added another benefit which is represented by:

7. The ability of reporting about the performance of maintenance areas during specified periods, helping to determine areas that are not functioning well, analyze the causes behind that, and categorize the errors and activities delay reasons, the possibilities of analysis statistics can be CMMS feature, storing the equipment technical features, and the stock files within a CMMS is an added advantage.
8. The ability of CMMS to track the history of maintenance costs and the future activities expenses make it as very useful maintenance budgeting tool.

Chapter Three
Criterion of Maintenance and Methodologies of Electrical and Electronic Equipments

Field observation and a questionnaire were conducted at different locations to have a deeper knowledge about maintenance practices and maintenance management for electrical and electronic equipment in AL-Abiad mine.

Beside observations and questionnaire, interviews with electrical team leaders and members were made. The outcomes results are presented as in the following sections:

3.1 Maintenance Policy

It is clear that the maintenance policy followed in AL-Abiad mine is corrective maintenance, other maintenance policies such as preventive and predictive are not practiced, preventive maintenance PM may be used in limited cases such as the hearing of noisy sound emitted from some equipment such as motors.

Nowadays, in particular there is no preventive maintenance plans exist for electrical equipments, while if a preventive maintenance plan exists it can minimizes the overall maintenance cost when it is executed for selected equipments.

The sole dependence on corrective maintenance is due to the unawareness of the importance of preventive maintenance at staff levels and the absence of the preventive maintenance culture. The lack of preventive maintenance work procedures at the time of retiring of old skilled personnel without activation of experience continuity by proper employment of gradually substitution of those skilled personnel before retiring is also main reason for preventive maintenance disappearance. Also by the mine management belief, doing extra work is not accepted while the electrical and electronic maintenance section is not sufficient in its existing form.

Corrective maintenance is performed each time an equipment or machine fails, sometimes failures are repeated and corrective maintenance is repeated without searching the failure root cause within a group meeting, corrective maintenance is mostly practiced as a treating of the symptoms of disease, not treating the disease itself.

Even if a preventive maintenance is required to be performed, there is no documentation that exactly describes the maintenance work procedures to follow each time a preventive maintenance action is to be made.

In general, because of the result of the desert dust environment where the mine is located and the phosphate dust emitted from the mine

processes, Preventive Maintenance PM is better choice to follow because it includes caring for electrical and electronic equipment and removing the accumulated dust which is considered as one of the causes for equipment failures.

On the other hand, adopting corrective maintenance only means high maintenance costs because equipment is left running until failure, so it needs to be repaired by spares change or equipment replacement. Most of the time the resulted costs for this kind of maintenance are more than in the case of preventive maintenance, considering the effects caused by that failure such as stopping production, environmental and safety impacts. This means that not all of equipments need to be listed in the preventive maintenance plan taking its failure frequency into account.

While most of the best practitioners of maintenance in the world follow the rule of mixing between corrective and preventive maintenance as per the percentages in table 3.1 (Sallivan et al., 2010), the status in AL-Abiad mine is as seen in the same table.

Table 3.1

Preventive and Corrective maintenance

Maintenance policy	AL-Abiad Mine	Best practices
Corrective	95%	55%
Preventive	5%	31%
Predictive	0%	12%
Other	0%	2%

By reliance on corrective maintenance, random breakdowns happen; the resulted losses are tons of phosphate material which could have been produced during downtime. Although data collection about number and period of the different mine units' downtimes due to electrical equipment failures are very difficult because of the unavailability of this data as it is almost not recorded whether by computer or on paper any way. The alternative was monitoring and recording these units' breakdowns and periods related to electrical equipment failures for one year. These data and the related production stop costs based on 90 JD/ton of produced phosphate as a price. Calculation results of the production losses and maintenance costs are presented in table 3.2.

According to Afefy (2012), Maintenance cost (*Cm*) and production losses cost (Cp) can be calculated by the following equations:

$$Cm = Csp + DT*Cv \quad (3.1)$$

Where,

Csp is the spare parts cost, it is equal to 12520 JD, 18700 JD, and 21450 JD annual at crushers, beneficiation, and dryers respectively.

DT is the down time; it is equal to 36 Hours, 65 Hours, 92 Hours annual at crushers, beneficiation, and dryers respectively.

Cv is the variable cost per hour of down time, it includes labor rate and crew size. It is equal to 6 JD/Hour for 10 persons, 13 persons, and 12 persons at crushers, beneficiation unit, and dryers respectively. Maintenance cost is equal to 14680 JD, 23770 JD, and 28074 JD annual at crushers, beneficiation, and dryers respectively.

The production losses cost (*Cp*) is estimated using the following formula:

$$Cp = DT * Plos * Sprice \qquad (3.2)$$

Where,

Plos is the production loss in unit per hour; it is equal to 50Ton/Hour, 50 Ton/Hour, and 90 Ton/Hour at crusher, beneficiation, and dryers respectively.

Sprice is the unit selling price of the product. It is equal to 90 JD/Ton.

The production losses are equal to 162000 JD, 292000 JD, and 745000 JD annual at crushers, beneficiation, and dryers respectively.

Table 3.2

Downtimes and loss of production costs due to reliance on corrective maintenance only during 10/2014 – 10/2015.

Production unit	estimated annual stop hours	Production loss cost JD/year	Maintenance cost JD/year	Total cost JD/year
Crushers	36	162000	14680	176680
Beneficiation	65	292000	23770	315770
Dryers	92	745000	28074	773074
Sum	193	1199200	66524	1265524

3.2 Repair Or Replacement

The decision to repair or replace failed equipment is not made with respect to cost; most of equipments are repaired while their replacement would have been more reasonable or less expensive.

In AL-Abiad mine, Motor is the main piece of electrical equipments that requires maintenance because of the motors large number, their failure effects, cost of repairing, and cost of replacement.

About 90% of motors that are sent to the motor workshop at AL-Abiad mine are rewound or repaired many times even though they have been in service since 1981 and they no longer being efficient as required, small size motors are also repaired or rewound even the cost of rewinding may exceed the cost of new replacement motor; motors are rewound or repaired while replacing might be more cost effective.

Other electric equipments are old and in service since 80s or 90s, there is an insistence to repair them in case of malfunction while replacing them with other efficient alternatives is more cost effective.

A necessary cost effective decision guide is required to repair or replace the failed motors as a best practice followed by major maintenance departments in the world. A decision to replace the defective equipments

such as motors in AL-Abiad mine motor workshop is taken only in case of inability to repair that piece because of serious malfunctions such as shaft curvature, stator slots defects, housing or covers being broken or unavailability of such pieces, etc.

Cost of rewinding different sizes of induction motors at the Mine motor workshop compared to the cost of purchasing new motor is presented in table 3.3. Cost of rewinding includes cost of material used in rewinding, Man- Hour cost, bearings cost, electricity consumption in rewinding, etc.

Table 3.3
Motor rewinding and purchasing costs

Motor size KW	cost of rewinding JD	cost of motor purchasing JD
7.5	310	626
11	390	833
15	460	1105
18.5	540	1325
22	610	1554
30	690	2055
37	800	2495
45	1100	3038
55	1550	3682
75	2050	4878
90	2700	5783
110	3350	7079
160	4250	10748

3.3 Electric Parts Storage And Inventory Control

Electrical spare parts or complete items are ordered from both outside manufacturers and their representatives in Jordan, the ordered quantities are determined by the electrical section head as an estimation of the coming two years maintenance need depending on the quantity of items consumed through the past years or as roughly estimation for the first time ordered items.

Spare parts are accumulated as dead stock because of failing to exactly forecast inventory demands, they are also accumulated because of modifications resulted in putting a lot of systems or equipments out of service leaving their spare parts as dead stock. Another reason noticed is that some items have more than one record and more than one location as well, as one of the records reaches zero level; the parts are reordered although they are available at the other location. Other items may be lost in the storeroom or not found due to moving it by an unauthorized person to other location while looking for some item, they may be undefined because their shelf cards were lost which is also enough to rationalize reordering these items. They may be overstocked or become dead stock.

There is a computerized system in the warehouses used only to update the inventory levels by manually entering movements while it should be used to control inventory levels depending on quantity level control system.

Purchase order is prepared by the store keeper for the fast consumed items that have simple and clear specifications recorded in their cards, more expensive items purchase order is prepared by maintenance engineer, at both cases order is prepared after zero or a little more quantity of some item is reached, so inventory level is depending on the memory of store keeper and maintenance technicians while it must be automated. Big maintenance problem may take place causing production loss and unavailability of machines with all costs incurred as a consequence of spare parts shortage.

Old paper cards are still used having hand written specifications that may be unclear, not enough, or even not identical to the actual. It also includes an updated inventory quantity.

Picking items is permitted by special form filled and signed by the maintenance section head and by the manager.

A team is annually formed from maintenance personnel and store keepers to conduct physical review and readjust inaccuracies in quantities, specifications, locations, validity of stock items, this team dose not do its duty properly, some members do not attend to the stores, some members take samples to check, this process is neither efficient nor reliable and is not beneficial in this way.

The warehouse building is very old; it suffers rain water leaks from the ceiling endangering the electrical installations and may cause shocks, electrical equipments and motors storing conditions are not suitable because of moisture, water leaks and dust, parts are covered by a layer of dust making it difficult to find some item, persons suffer because of the dust accumulated on the parts. Cable reels and transformer oil drums are stored improperly out of storeroom which may exposes them to damage or early expiry.

Items are put on shelves which are marked by codes to distinguish items locations; these codes are not clear or sometimes missed. Store keeper can find the location by his experience, at afternoon and night shifts there is no assigned storekeeper; it is difficult for maintenance technicians to find some necessary spare parts at these times which could cause delay in maintenance activities with the related costs.

Some items such as motors are not well stored, they are left directly on the floor between shelves making crowded paths, and also lighting is not enough which may hinders finding some item when needed at emergency maintenance cases.

The best practices include well arranged stores; items can be easily reached and picked. Spare parts are cleaned and have clear codes to reduce

the time needed in the storage. Also conditions of electrical spare parts and complete items storage such as temperature, humidity, dust free should be suitable.

Inventory control which includes availability of spare parts with the right quality, right quantity on the right time is a best practice that should be followed.

Dead stock financial value was estimated to be 500,000 JD for all the warehouse spare parts, for electrical spare parts the value was estimated to be 100,000 JD.

3.4 Power Quality Problems

There are many damaging types of power quality disturbances that electronic systems may encounter such as: Power surges, high – voltage spikes, transients, frequency variation, power sag, electrical line noise, brownouts.

Many computer screens, printers, fluorescent lamps were damaged at different facilities in AL-Abiad mine which must be replaced to add more costs to the overall maintenance cost. Data loss and efforts to retrieve it back is another cost that should be accounted for. Direct incurred costs and production loss cost during 2015 due to bad power quality were 5361 JD.

Bad power quality may leads to turning power off incurring the mine major costs. Hidden costs resulted because of bad power quality may include shortening life time of different major electrical equipments such as motors and transformers.

3.5 Power Factor PF

Power Factor PF is a measure of electrical network efficiency, it is the ratio of active power that consumed by the load to the apparent power delivered to the load (Abd Allah, 2014), PF value in the mine electricity bill ranges between 0.79 to 0.86, surely it must be corrected to reach more than 0.9 avoiding financial penalties imposed by NEPCO (National Electric Power Company) which were 15484 JD during year 2015.

In the past, PF in the mine network was corrected by using central capacitor bank, which was disconnected, put out of service, and replaced by capacitors connected individually to chosen induction motors at the beneficiation and drying units.

It is found that the electrical rooms where the capacitors are connected is opened all the time, capacitors and contactors are covered with dust, even it is cleaned, dust will accumulate soon. Dust causes contactors to fail, which put these capacitors out of operation, causing power factor to be reduced.

3.6 Indoor Lighting

Mainly, a fluorescent lighting system is used in AL-Abiad mine offices, housing and service utilities; each fluorescent lighting system includes the fluorescent lamp, the ballast, and the starter system.

Beside the high energy consumption compared to the new energy saving lighting technologies, fluorescent lamps life time is lower and its parts must be continuously replaced which increase maintenance efforts and costs.

No periodic maintenance or periodic relamping, no lamp cleaning is performed, lamps are changed only on request, while the best maintenance practices state that lamps should be checked periodically and relamping is done during the periodic maintenance.

Annual indoor normal lighting costs are 45552 JD while costs due to working for excess 16 hours are 56190 JD.

3.7 Outdoor Lighting

Streets and mine facilities lighting is limited to 300(250 watt) and 100(400 watt) mercury and sodium lamping technologies which also have lower life times and more maintenance needs compared to other new energy saving street lighting technologies.

The mine street lighting is not periodically checked or relamped, while maintenance best practices include periodic maintenance and relamping. Relamping is done after complaint of persons at night shift, their complaint about illumination weakness aims to enhance the mine security and enable them to perform their night jobs correctly. Vehicle that used for outdoor lighting relamping and maintenance is very old, unsafe, and suffers many technical problems, which may hinder relamping and maintenance activities.

For lighting control, Photocell is used to turn street lamps ON and OFF at evening and morning respectively, also electric circuit breakers are used to turn ON and OFF group of lamps at the mine outdoor facilities, these breakers are left ON for hours over the day.

Annual normal costs are 129168 JD while costs due to excess work are 5850 JD.

3.8 Electrical Equipment Specifications

All motors are purchased with standard efficiency specifications, instead of high efficiency and premium efficiency motors which have main role in saving energy with small difference higher in prices. Insisting to buy standard efficiency motors makes maintenance to lose the opportunity to save money and maintain the reliability.

Motor specifications in AL-Abiad mine should include higher degree of Protection enclosure IP which is the level of protection against

liquids and solids for all motors in service. Motors in service are IP 54 or IP 55, motors with such protection classes are not entirely dust protected in a very phosphate dusty environment, and the protection against water jets is not enough while beneficiation unit needs at some places more protection class. Hence at beneficiation unit where water leakages are mostly exist; a lot of motors are burnt out monthly while they are still purchased with low degree of protection against liquids, beneficiation unit motors are not designed to work within these conditions.

Dust causes serious contact failure when it exists between the contacts which eliminate protection or control functions (Jinchun & Gang, 2012), Dust contamination when moisture exists may cause short circuit at connection boxes and electrical equipments damage, accumulated dust on motor housing decreases cooling causing motor to fail, the incurred costs result may include cost of the damaged equipment maintenance or replacement and the losses of stopping production.

Also, if it coincides with rain water, dust contamination on the insulators of the over head power transmission line decreases the efficiency of these insulators, which may cause power failures.

Another notice is that electrical maintenance engineers insisting to replace the very old and defected electrical equipments or components such as air circuit breakers and contactors by the same type and model, from the same manufacturer with high prices. Manufacturers may justify high prices by operating their very old production lines which operated only after purchase order reception, while there are a lot of state of the art replacements and alternatives at different manufacturers available in the market with lower prices, higher efficiency and can perform the same function.

Power failure for 4 hours has stopped all mine production for 4 hours as a result of bad insulators situation as they have not been checked, cleaned, and replaced in case of defect for a long time. Cost of production losses are presented in table 3.4.

Table 3.4
Cost of production loss due to improper insulators maintenance and specifications.

Unit	Downtime (Hours)	cost JD/Hour	Production loss costs JD
Crushers	4	4500	18000
Beneficiation	4	9000	36000
Dryers	4	8100	32400
Sum			86400

During year 2015, 12 motors were burnt out, 4(45 KW), 3(90 KW), 2(55 KW) and 3(11 KW) due to exposure to water. Also 2 motors (30 KW)

and 3(45 KW) during the same year were burnt out due to dust accumulation. If 17 motors with the mentioned sizes above are supposed to be burnt out annually, the rewinding, maintenance and stop losses costs are detailed in table 3.5.

Table 3.5
Motors rewinding, maintenance costs, and production stop losses due to improper specifications.

Motor size KW	motors quantity	cost JD	cost JD/year	Unit	Production loss costs JD
45	4	1100	4400	Beneficiation	21600
90	3	2700	8100	Beneficiation	16200
55	2	1550	3100	Beneficiation	10800
11	3	390	1170	Beneficiation	16200
30	2	690	1380	Crushers	27000
45	3	1100	3300	Crushers	40500
Sum	17	7530	21450		132300

3.9 Motor Speed Control

Electronic speed control systems for motors are not used any way in AL-Abiad mine, where a lot of applications can be incorporated by such systems to reduce power usage by matching motor speed to the required load. The best practices of electrical maintenance have witnessed installing such equipments at the industrial facilities.

Load control of five filters at the beneficiation unit in Al-Abiad mine is not performed efficiently because the 90 KW motor, 1500 RPM speed is reduced mechanically to 700 RPM using pulleys. It is not possible to decrease the speed less than that due to shaft and pulley diameter limitations. Load speed is required to reach 350 RPM to suite the process requirements.

Operators and labors are used to move these motors on a sliding mounting base by loosening the bolts in order to tight or slip the belts on the pulleys to change the load speed. This process is very tiring as it may be repeated many times a day, not practical, and finally does not achieve the required speed.

Speed of suction fan motors 4(160 KW) can be controlled at the dryers to improve the product quality in addition to the power savings. Also speed of fuel supply pumps at dryers can be controlled to save more power and fuel in addition to the safe environment of operation it provides by supplying the suitable quantity of fuel to the burners.

Motors that continuously work at its maximum speed may have shorter life duration and need more maintenance works due to more stress on the rotating parts and windings and insulation.

Motor operation at maximum speed causes higher vibration problems that always drive up maintenance costs and production downtime.

Due to running 5(90 KW) motors by their maximum speed and the mechanical processing of loosening motor feet bolts, while motor should be well fixed and no caused vibration, repeated costs are incurred because of motor broken feet, bearing malfunction, motor failure , and production loss. These costs are estimated and detailed in table 3.6 as per the last year.

Table 3.6

Motors maintenance costs & production loss costs due to improper speed control mechanism.

Type of Cost	Event/Year	Cost JD/Year
Feet replacement	15	1875
Rewinding	1	2700
Production stop losses For 1 hour	15	67500
Production stop losses For 3 hours	1	13500
Sum		85575

3.10 Maintenance Work Space And Time Delay

Pipes at beneficiation plant were replaced over the years, their paths were modified, space over floors is very crowded by eroded pipes and water leakage is every where. As a result the maintenance activity to remove the failed motor and fix new one became very difficult task; it extends the time needed to replace the failed motor and increases the incurred costs because of stopping production during that time.

Productivity in maintenance can be increased and mean time to repair MTTR can be improved by keeping suitable workplace for components handling, personnel movement, it is an interested issue in the industrial facilities as one of the best practices.

Time is production, delay to replace the failed motors at the beneficiation unit resulted because of modifications and crowded work area is estimated to be one hour each time a motor is replaced at that area. Motors that took more time to be replaced during year 2015 are detailed in table 3.7 with the resulted costs of delay.

Table 3.7

Costs resulted because of 1 hour delay in replacing motors in the crowded areas.

Motor size KW	number of events	production loss cost JD/year
90	6	27000
55	5	22500
11	3	40500
Sum		90000

3.11 Measurement Instrumentations And Control Systems

Since 1980, the date of establishing Al-Abiad mine, instrumentation systems such as process controllers, indicators, and recorders of temperature, level, pressure and density, alarm systems, indication lamps, counters and some protection systems such as proximity switches, motor thermostat switches, are now out of service because of lack of specialized persons to deal with these systems.

Because of high failure rate and the difficulty of repairing and maintenance of these devices, successive administrations preferred to put them out of the operation circuits to stop production losses related to those devices.

Putting these devices out of service has led to operating the mine machines and equipment without control, running unsafely, unsafe for labors and equipments.

Interlocking system between equipments which was represented by traditional relaying system was cancelled due to complexity, recurring failures, and maintenance problems. As a result, a lot of equipments are now running and operated without interconnection with other equipments, production units are not operated as they were designed. They are operated unsafely, resulting in out of specifications products, lower mine efficiency, consuming higher electricity, water, labor efforts.

It was very difficult to calculate costs that resulted because of the large deviation of the existing mine process control from the original design. Instead the impact of not using one type of instrumentations which is motor temperature sensors has been studied.

Sensors can detect dangers and malfunctions before major failures and accidents happen. Electric motors failures due to winding high temperature that have not been connected to temperature probes are shown in table 3.8 with the resulted costs of maintenance and production losses.

Table 3.8

Annual costs resulted because of motor failures due to winding which have not been connected to temperature probes.

Motor size KW	number of events	Stop hours	production loss JD	maintenance cost JD	JD/year cost
90	2	3	27000	5400	32400
110	1	3	13500	3350	16850
160	1	3	24300	4250	28550
Sum			64800	13000	77800

3.12 Oversized Motors

Observations, old maintenance personnel notes show that several motors in AL-Abiad mine were replaced with greater power motors, the reasons to replace these motors were:

I. Motors can not operate the load, they were considered as overloaded and should be replaced with greater power ones, while the reason may be pipes were clogged.
II. Motors were replaced by greater power ones at the time of deciding to resize the pipes diameter without deep study and calculations.
III. Other motors were replaced by greater power ones at the time of un availability of the same size, each time these motors fail, maintenance used to replace them by the new size motors. The following table shows some details of the resized motors.

Table 3.9
Oversized motors in AL-Abiad Mine

Unit	process	original size	new size	No. of Motors
Beneficiation	Tunnel water Pump	5.5 KW	7.5KW	3
Beneficiation	Sump pump	7.5KW	11KW	2
Crushers	belts	15KW	18.5KW	1
Beneficiation	cyclones	22KW	45KW	4
Crushers	screens	7.5KW	11KW	3
Dryer 4	suction fan	160KW	240KW	1

According to Bureau of Energy Efficiency, Indian Renewable Energy Development Agency, and Devki Energy Consultancy Pvt. Ltd. (2006), Problems resulted because of oversized motors are**:**

1. Lower power factor which causes higher maximum demand.
2. More cable losses and demand charges.
3. Higher costs of rewinding in case of burnout.
4. Higher installation costs.

Chapter Four
Results And Discussions

This part of the study discusses and presents cost effective solutions, good practices, and new alternatives in terms of reducing maintenance costs and energy consumption based on the observations and data collected from AL- Abiad mine.

4.1 Maintenance Policy

Because electrical equipments are still being operated unsafely, and not maintained correctly, relaying on corrective and run to fail maintenance strategies alone is not cost effective, it indicates that other proactive scenarios should be adopted and added to the existing used corrective scenario.

PM adoption is simple, it becomes routine job over time, most of the time equipment needs to be stopped to perform PM procedures, which is possible in AL-Abiad mine due to the existing process design and the possibility to stop certain production units such as crushers while beneficiation unit can consume the stock of crushers product. Also some dryers can be stopped while others can consume beneficiation accumulated product.

Due to the presence of the mine in dusty place as well as the addition of phosphate dust, this make adoption of preventive maintenance an important issue, at least to remove the accumulated dust that causes many electrical malfunctions. If this is added to the other benefits, adoption of PM is an urgent need.

"Electrical equipment deterioration is normal, but equipment failure is not inevitable. As soon as new equipment is installed, a process of normal deterioration begins. Unchecked, the deterioration process can cause malfunction or an electrical failure" (National Fire Protection Association (NFPA 70B), 2006, P. 13).

4.1.1 Benefits of electrical preventive maintenance (EPM)

Carrying out preventive maintenance of the electrical equipments and machines may result in the following benefits:

1) Reducing the maintenance cost, as PM prevents major and sudden breakdown of machines and equipment, equipment breakdown incurs higher costs to repair or replace, it takes longer time to restore the equipment to normal operation (NFPA 70B, 2006).
2) Implementing effective PM keeps the machines running healthy which improve labor safety (A. Jain, 2012), reducing the medical expenses, and increasing labor moral and productivity.

3) Due to fewer machines breakdowns, production downtime will be reduced (A. Jain, 2012), increasing profitability and saving of production losses due to delay.
4) Better conservation of assets and increase their life time, thus preventing premature replacement (A. Jain, 2012) this will postpone purchasing new machines.
5) Reducing overtime costs (A. Jain, 2012) because of the cost effective scheduling of the maintenance resources.
6) Operating Equipment and machines in healthy conditions increases its efficiency. Higher efficiency equipment consume less energy (NFPA 70B, 2006).
7) Reducing repairs cost by reducing secondary failures. When parts fail they cause other parts damage (A. Jain, 2012).
8) Identification of equipment having excessive maintenance costs, supporting a decision to make corrective action, replacement, redesign, or maintenance and operator training (A. Jain, 2012).

4.1.2 Electrical preventive maintenance EPM establishment

EPM must be based on knowledge of:

1- The equipment and machines that should be included in the PM list.

The tables below include equipment and machines at different locations in AL-Abiad mine, beneficiation unit is excluded.

Table 4.1

Substation suggested electrical equipment preventive maintenance schedule.

Item	Manufacturer	Date of Manufacturing	Notes
Transformer	Bonar long	1980	10MVA- 33
Power line	NA	1980	33 KV
Auxiliary TR.	Bonar long	1980	6.6KV/400V
Charger	BBC	1985	12 KV
Batteries	VARTA	1985	200 AH, 6 V
Oil circuit breaker	BBC	1985	412 A
Oil circuit breaker	BBC	1985	412 A
Oil circuit breaker	BBC	1985	412 A
Oil circuit breaker	BBC	1985	412 A
Oil circuit breaker	BBC	1985	412 A
Oil circuit breaker	BBC	1985	412 A
Oil circuit breaker	BBC	1985	412 A
Oil circuit breaker	BBC	1985	412 A
Oil circuit breaker	BBC	1985	412 A

Table 4.2

Crusher No.1 suggested electrical equipment preventive maintenance schedule.

Item	Manufacturer	Date of manufacturing	Notes
Transformer	Siemens	1977	6.6KV/400V
Air circuit breaker	Siemens	1979	2500 A
Air circuit breaker	Siemens	1979	2500 A
Air circuit breaker	Siemens	1979	1600 A
Air circuit breaker	Siemens	1979	630 A
Air circuit breaker	Siemens	1979	320 A
Power Factor Corr.	HAEFELY S.A	1979	360 KVAR
Feeder Motor M1	AEG	1984	18.5 KW
Vibrating screen M2	AEG	1984	30 KW
Conveyor M3	AEG	1984	15 KW
Crusher motor M4	SCHORCH	1981	110 KW
Conveyor M5	AEG	1984	22 KW
Vibrating Screen M6	AEG	1984	11 KW
Conveyor M8 Drum Motor	ABM	1982	5.5 KW
Conveyor M9	ASEA	1984	18.5KW

Table 4.3

Crusher No2 suggested electrical equipment preventive maintenance schedule.

Item	Manufacturer	Date of Manufacturing	Notes
Air circuit breaker	Siemens	1979	1600 A
Power Factor Corr.	HAEFELY S.A	1980	360 KVAR
Feeder Motor M1	AEG	1984	18.5 KW
Vibrating screen M2	AEG	1984	30 KW
Conveyor M3	AEG	1984	15 KW
Crusher motor M4	SCHORCH	1981	110 KW
Conveyor M5	AEG	1984	22 KW
Vibrating Screen M6	AEG	1984	11 KW
Conveyor M8 Drum Motor	ABM	1982	5.5 KW
Conveyor M9	ASEA	1984	18.5 KW

Table 4.4

Dryer No.1 suggested electrical equipment preventive maintenance schedule.

Item	Manufacturer	Date of Manufacturing	Notes
Transformer	Siemens	1977	6.6 KV/400 V
Air circuit breaker	Siemens	1979	1600 A
Air circuit breaker	Siemens	1979	1600 A
Power factor	HAEFELY S.A	1985	60 KVAR
Waste air fan motor	Siemens	1981	160 KW
Combustion air fan motor	Siemens	1981	75 KW
Dilution air fan motor	Siemens	1981	45 KW
Rotary dryer motor	Siemens	1981	90 KW
Fuel oil pump motor	AEG	1984	2.2 KW
Conveyor 502 A.1	ASEA	1985	22 KW
Conveyor 501	ASEA	1985	7.5 KW
Rotary atomizer	ASEA	1985	15 KW
Belt scale	Cardinal	2009	100 Ton/h

Table No. 4.5

Dryer No2 suggested electrical equipment preventive maintenance schedule.

Item	Manufacturer	Date of Manufacturing	Notes
Transformer	Siemens	1977	6.6KV/400V
Air circuit breaker	Siemens	1979	1600 A
Air circuit breaker	Siemens	1979	1600 A
Power factor	HAEFELY S.A	1985	60 KVAR
Waste air fan motor	Siemens	1981	160 KW
Combustion air fan motor	Siemens	1981	75 KW
Dilution air fan motor	Siemens	1981	45 KW
Rotary dryer motor	Siemens	1981	90 KW
Fuel oil pump motor	AEG	1984	2.2 KW
Conveyor 502 A.1	ASEA	1985	22 KW
Conveyor 502	ASEA	1985	7.5 KW
Rotary atomizer	ASEA	1985	15 KW
Belt scale	Cardinal	2009	100 Ton/h

Table 4.6

Dryer No.4 suggested electrical equipment preventive maintenance schedule.

Item	Manufacturer	Date of Manufacturing	Notes
Transformer	Siemens	1977	6.6KV/400V
Air circuit breaker	Siemens	1979	1600 A
Air circuit breaker	Siemens	1979	1600 A
Power factor	HAEFELY S.A	1985	60 KVAR
Waste air fan motor	Siemens	1981	160 KW
Combustion air fan motor	Siemens	1981	75 KW
Dilution air fan motor	Siemens	1981	45 KW
Rotary dryer motor	Siemens	1981	90 KW
Fuel oil pump motor	AEG	1984	2.2 KW
Conveyor 502 A.1	ASEA	1985	22 KW
Conveyor 502	ASEA	1985	7.5 KW
Rotary atomizer	ASEA	1985	15 KW
Belt scale	Cardinal	2009	100 Ton/h

Table 4.7

Other electrical equipment suggested preventive maintenance schedule.

Item	Manufacturer	Date of Manufacturing	Notes
Diesel Emergency Unit			
Generator	VEM	1980	100 KVA
Engine	Cummins	1980	127 HP
Main offices lighting	Osram	NA	40 Watt
Housing A lighting	Osram	NA	40 Watt
Work shop indoor lighting	Osram	NA	40 Watt
Housing B lighting	Osram	NA	40 Watt
Out door beneficiation lighting	philips	NA	250 Watt
Street lighting	philips	NA	250 Watt
Dryers outdoor lighting	Philips	NA	400 Watt
Operation indoor lighting	Osram	NA	40 Watt
Yards lighting	Philips	NA	250 Watt
UPS systems	Bpc, AROS	2010	20KVA,800KVA
Bridge scales	Cardinal	2009	70 Ton
Service Transformer	Ponar	1980	6.6 Kv/380 v

Table 4.8
Water wells 1 and 2 suggested preventive maintenance schedule.

Item	Manufacturer	Date of Manufacturing	Notes
Well NO.1 Transformer	Siemens	1977	250KVA
Autotransformer	K factor	2008	
Motor	Siemens	2010	90KW
Motor circuit	Schneider	NA	
Lighting	Osram	NA	
Capacitors	Aples	2011	60KVAR
Well NO.2 Transformer	Siemens	1977	250KVA
Autotransformer	K factor	2008	
Motor	Siemens	2010	90KW
Motor circuit	Schneider	NA	
Lighting	Osram	NA	
Capacitors	Aples	2011	60KVAR

Table No. 4.9
Water wells 4, 5 and10 suggested preventive maintenance schedule.

Item	Manufacturer	Date of Manufacturing	Notes
Well NO.4 Transformer	Ponar	1980	250KVA
Autotransformer	K factor	2009	
Motor	ABB	2007	90KW
Motor circuit	ABB	NA	
Lighting	PHILIPS	NA	
Capacitors	Aples	2011	60KVAR
Well NO.5 Transformer	Ponar	1980	250KVA
Autotransformer	K factor	2009	
Motor	ABB	2007	90KW
Motor circuit	ABB	NA	
Lighting	PHILIPS	NA	
Capacitors	Aples	2011	60KVAR
Well NO.10 Transformer	Ponar	1980	250KVA
Autotransformer	K factor	2009	
Motor	ABB	2007	90KW
Motor circuit	ABB	NA	
Lighting	PHILIPS	NA	
Capacitors	Aples	2011	60KVAR

2- Action taken.

This includes the maintenance procedures that should be performed by the maintenance technicians.

The procedures are arranged in APPENDIX I, depending on NFPA 70B standard, manufacturers’ manuals and recommendations if available.

3- Periodicity plan.

The suggested equipment maintenance cycles is shown in the Appendix I, cycles have been selected depending on National Fire Protection Association NFPA 70B (2006) standard, manufacturer recommendations, and the accumulated experience of AL-Abiad mine

electrical maintenance team, it is suggested to increase these frequencies because of the dusty environment to mitigate the dust effects and reduce the related electrical failures.

In this respect it was found out that lots of manufacturer's manuals were lost, some of them are very dirty and difficult to use because they were not well kept.

Also it was not possible to get manufacturer manuals on the internet because some of these equipment original manufacturers were sold to other companies, for example BBC Company were purchased by ABB and it is not available any way, its products were completely changed.

Other manufactures equipment PM procedures can not be specially followed because of the availability of many brands, instead general or standard procedures are suggested and followed.

4- Maintenance activities that must be communicated, reported, and documented.

For these points, mentioned above, it was found that software program must be developed to facilitate preventive maintenance activities, this software was developed using ACCESS and VISUAL BASIC, it may include the following features:

1. Adding all the equipment included in the PM list.
2. Scheduling the maintenance activities along the calendar year taking into account the yearly production plan, distribution of the maintenance activities with the least possible costs and facilities stopping.
3. Adding the assigned employees who will perform the PM jobs.
4. Inserting the procedures that should be followed by the technicians.
5. The ability to automatically send an E-MAIL to the assigned personnel on the scheduled time. This E-MAIL shows the equipment name, and the procedures that should be followed.
6. After completing the maintenance job, the assigned personnel can make report by replying an E-MAIL to the electric maintenance section head, this report should contain completion data such as cost of the used spare parts, names of the technicians performed the maintenance job, number of hours it took to complete the job, any notes related to the equipment state and its need for correction maintenance.
7. Different maintenance reports can be prepared and printed to continuously review the actual level of the maintenance and the effect of PM on the equipment reliability, productivity, availability, breakdown time reduction, and maintenance costs reduction.

Reviewing PM effectiveness may be done by maintenance performance indicators such as MTBF (mean time between failures), MTTR (mean time to repair) which can be obtained from other records if they are available.

The developed PM software includes preventive maintenance time to the overall maintenance time ratio as performance indicator to be used as feedback and measurement of the efficiency of the performed preventive maintenance plan.

The following figures are screen shots obtained from the developed software, these screen shots represents the user windows. The software code is found in Appendix II.

Figure 4.1
Login Screen

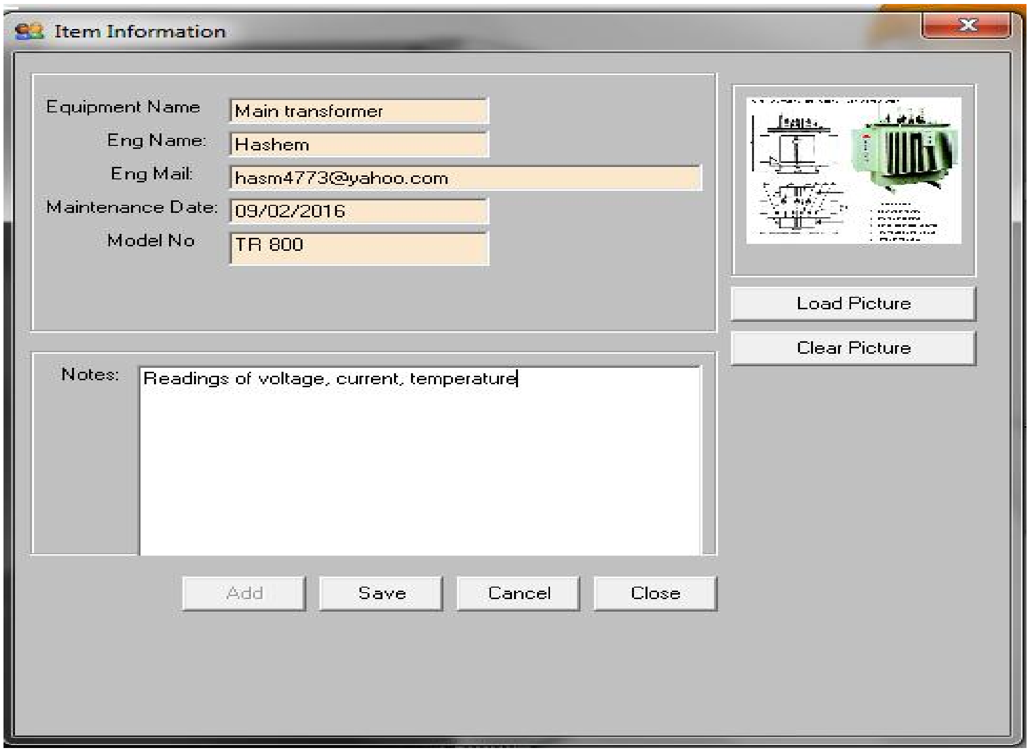

Figure 4.2
Equipment details insertion.

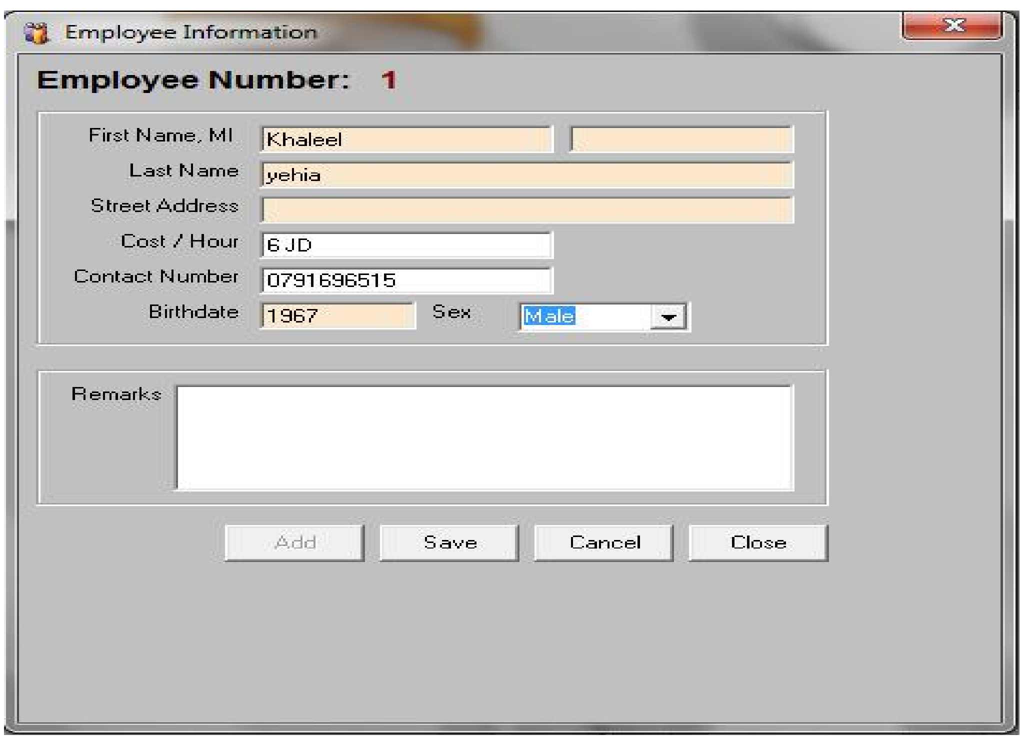

Figure 4.3
Technician data insertion Window.

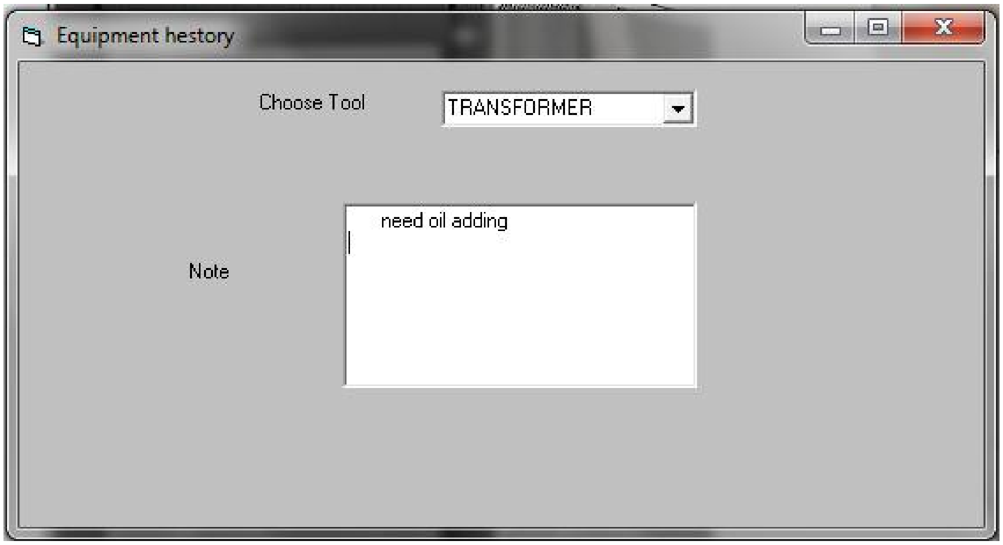

Figure 4.4
Equipment history Window.

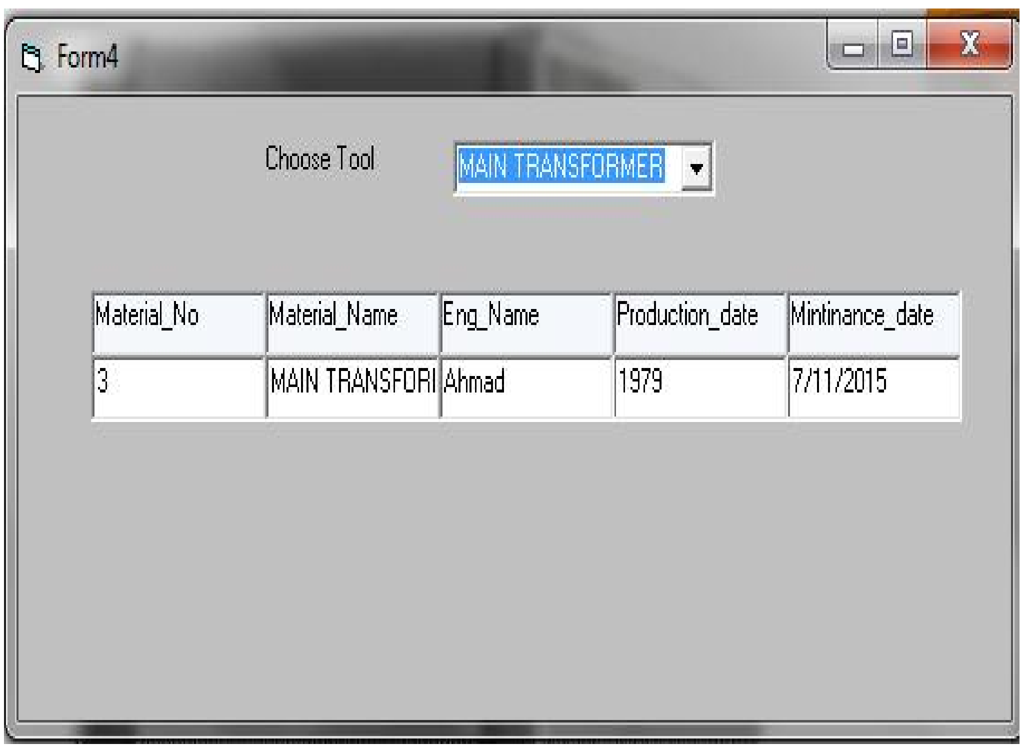

Figure 4.5
Equipment record.

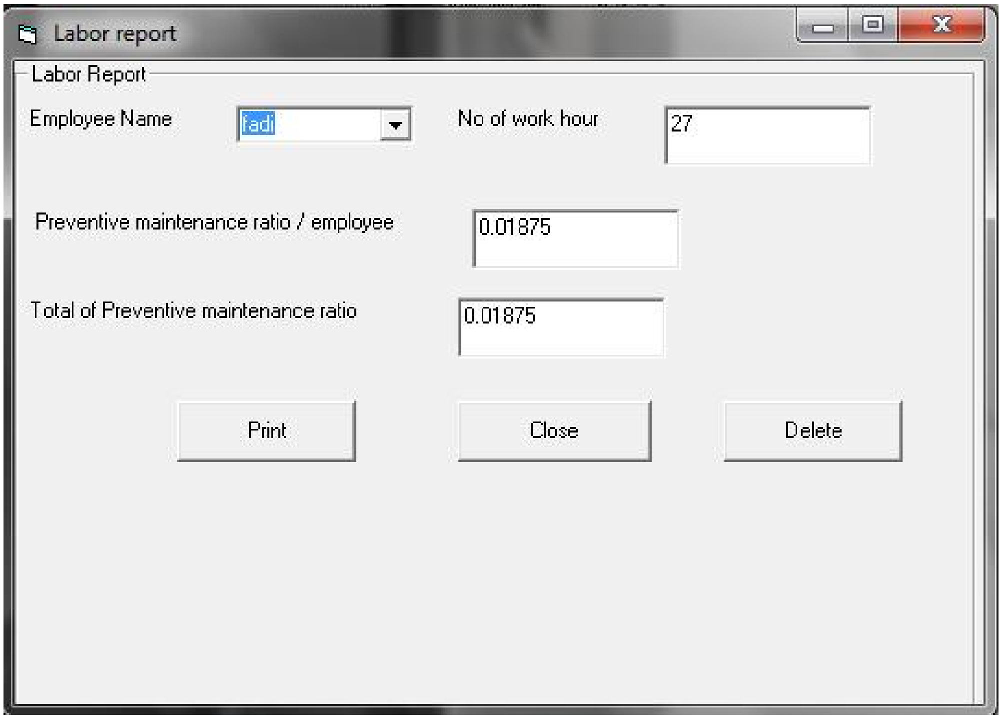

Figure 4.6
Technicians work hours Report Window.

Figure 4.7
Equipment Maintenance Costs

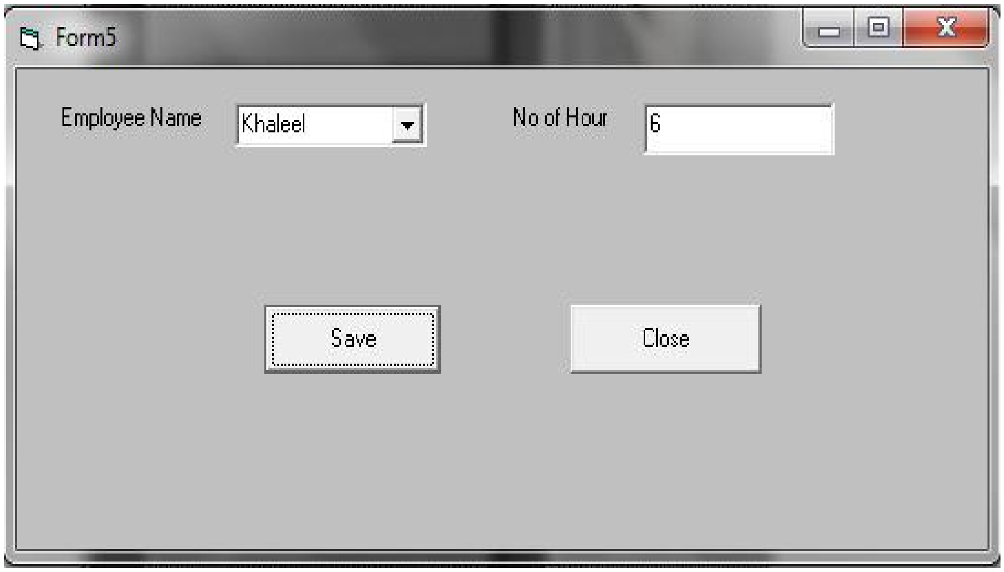

Figure 4.8
Labor work hours adding window

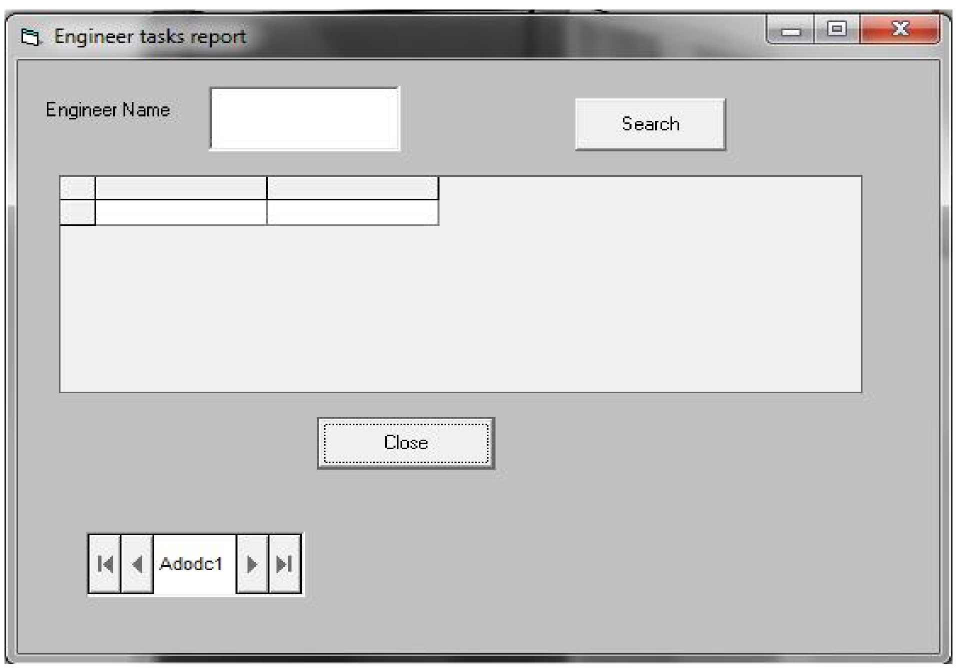

Figure 4.9
Engineer Task Report

Figure 4.10
Password Change window

Vijay, Rao, and Kumar (2013) state that implementing a proper PM plan in facilities that purely reliant on reactive maintenance could save up to 18% of the maintenance costs. Hence, by implementing Preventive maintenance plan in the mine electrical maintenance department and depending on data given in table 3.2, the costs of maintenance and production losses could be reduced as shown in table 4.10 below, savings which might be gained are presented in fig. 4.11.

Table 4.10
Cost Of Maintenance and Production Before and After Implementing PM Plan.

Unit	Costs JD/year Before implementing PM	Costs JD/year after implementing PM
Crushers	176680	144877.6
Beneficiation	315770	258931.4
Dryers	773074	633920.68
Sum	1265524	1037729.68

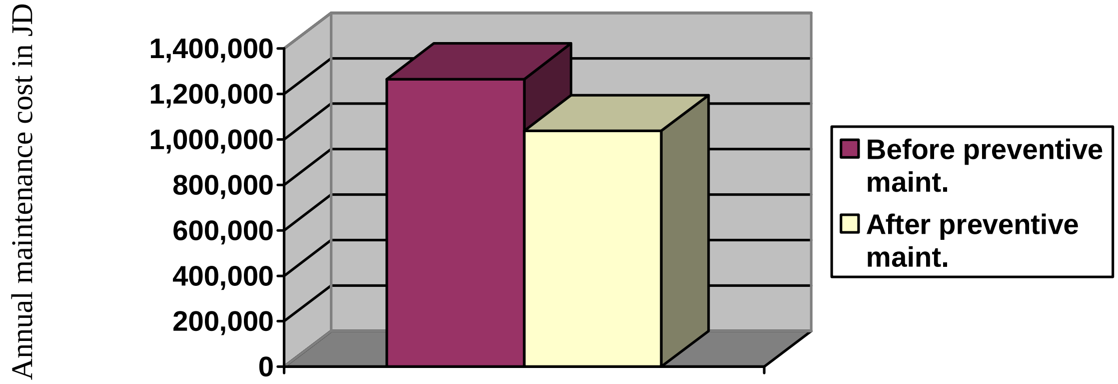

Figure 4.11
Savings in JD by implementing preventive maintenance on electrical equipments.

4.2 Warehouses And Inventory Control

In spite of the fact that warehouses and inventory control is the responsibility of the warehouses and supply chain department, maintenance find it self as partner in different activities and processes. Maintenance department is forced to push and assist to reduce the level of the inventories to a considerable level without any harmful effects on production, by using inventory planning and control techniques, the reduction in excessive inventories leads to favorable impact on company profitability (Vaisakh, Dileeplal, & Unni, 2013).

It can be said that the warehouses main building is in need to be revamped to be suitable as a store room for costly electrical and electronic materials at different weather conditions, to be appropriate in winter and protects against rain water, moisture, rust, and dust as well . Special store room should be established with cooling facility for electronic cards and parts.

One of the main problems warehouses are facing is the dead stock or items that have not been used for long period of time, that arise as a result of many practices, significant costs related to continuity in keeping these dead items in the store rooms. If some part is kept in the store room for one year, this can add part of its capital cost, it will take little years to double the cost of a spare part. Significant costs can be accounted when hundreds of parts are still stored since ten years or more and never used.

Dead stock is dead money, if it costs money to keep usable parts, surely it will cost more to store unusable parts. This includes the cost of storage or servicing including cleaning, moving, checking, and counting at the annual review, salaries of the store keepers and other administrative costs are also distributed over all items inventory whether they are usable

or not (Bharadwaj, Silberschmidt, & Wintle, 2011). Also Holding or carrying cost may include insurance cost, taxes on inventory, and cost due to the possibility of damage, theft, or obsolescence, but the most important is the opportunity cost incurred by tying up capital in inventory (Bharadwaj et al., 2011).

Procedures should be taken to solve this problem. Checking and testing all of these items may shows defected, corroded, worn out, cannibalized items. Selling those as scrap saves storing costs and adds their salvage money as returns.

Putting the new purchased items in the same inventory record of the old items that have the same specifications and the same function may reduce the size of dead stock. Lots of the old stocked spares were converted to dead stock because the new purchased items are withdrawn and consumed while the old items are left on the store shelves.

Suggestion was presented to write to the other locations of JPMC to visit the mine storehouse and check whether these dead stock items can be used at these locations, if yes, these items may be converted to usable parts and the financial value is reinvested.

The annual inventory review should be more active, members of the review team should be concerned with:

1. Consolidate the identical items that have more than one record.
2. Check and test stored items for their validity.
3. Remove defected items or those need repairing.
4. Members must be sure that store room items inventory quantities, locations, and the clear specification on the records or the computer print out record are identical to that in the shelves.
5. Report the storage conditions for the different items classifications.
6. Specifications should be reviewed and rewritten clearly and per part number to facilitate reordering process.

Holding large numbers of every spare part would minimize the facility downtime, but the costs of purchasing and storing stock would be excessive, so minimizing the sum of direct costs of purchasing and storing spares and indirect costs of production loss due to waiting for spares is the rational objective of running spare parts and controlling its inventory (Kelly, 1997).

Management of spare parts concentrates on having a clear guideline as to identify: which items should be kept in stock, how many of that item must be ordered at once, how many pieces must be kept in stock, and when a new order should be released (Bosnjakovic, 2010).

Absence of clear criteria to have a decision about stocking an item or not may lead to un stocking critical items. Analyzing items explains that they do not have the same importance according to equipment operation without downtime, work safety, and procurement cost, Bosnjakovic (2010)

proposed a model to help in deciding about keeping an item in stock or not, his model depends on ranking items by value usage, by criticality, and by frequency of demand, each rank is graded into three groups, while each stock item can be defined with three parameters:

(Value –usage, frequency of demand, criticality), parameters can have three values, so the total number of possible combinations is 27 which can be explained by the three dimensions model of cubes in figure 4.12 (Bosnjakovic, 2010).

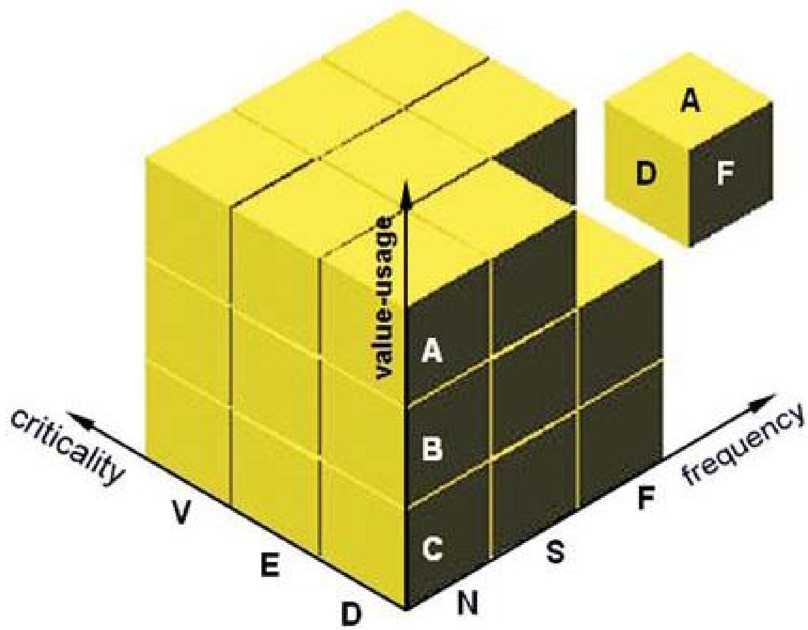

Figure 4.12
Possible combinations of parameters for spare parts ranking purposes.
Source: (Bosnjakovic, 2010)

But this criterion assumes that it is easy to contact the manufacturers and it takes short time to get the required items, or you may depend on JIT (Just in Time) supply method. Here in Jordan most of the spare parts are imported over seas, this criterion may cause significant downtimes as a result of equipment or spare parts shortage or arrival delay, considering spare parts delivery times are not committed because of freight and manufacturer technical conditions.

Stock levels and reorder quantities or demand levels always depend on historical data including the consumed quantities over the past two years. There are many techniques that can be used to forecast parts demand depending on statistical distributions. Demand forecasting is easier after classifying spare parts to categories to prioritize managerial effort and for

inventory control purposes, to forecast demand of category is better than it for each spare part (Rego & Mesquita, 2010).

Re order quantity Q for some item can be identified from the following expression (Kelly, 1997).

$$Q = \sqrt{(2DC0/Ch)} \qquad (4.1)$$

Where D is the mean demand for the part per unit time,
C0 is the cost of the replenishment order,
Ch is the cost, per item, of holding the part.

If the mean demand D for 3*6 sq.mm cable in the mine is 1090 m yearly, the cost of the replenishment order C0 is 20 JD, and the cost of holding that cable is 0.75 JD, the re order quantity Q will be 242 m.

The re order level M can be calculated from the expression (Kelly, 1997).

$$M = DL + k\sigma d\sqrt{L} \qquad (4.2)$$

Where L is the mean lead time,
σd is the standard deviation of demand per unit time,
k is the standard normal variate, is a function of probability of item demand being met during a lead time.

There are much software in the market used to forecast spare parts demand, having such that software can help in accurately forecasting spares demand depending on the historical data, which save costs incurred because of overstocking resulted from over estimation of spares demand and avoid the risk of under estimation and its consequences. Further more such software can monitor changes in spares demand and automatically adjust reorder level and quantity (Kelly, 1997).

At the industrial complex – one of the JPMC sites – critical spares are listed in an A.F.S.R (authorized for stock requirements) system which contains minimum level, reorder level, and the maximum level of the stocked parts, these quantities were set roughly by maintenance and supplying employees depending on the historical data without using software, these quantities are readjusted as needed to suite maintenance requirements, the inventory are reviewed periodically twice a year to reorder parts that reach reorder level.

In AL-Abiad mine periodic review to reorder parts is not used, the inventory is continuously monitored and when the level reaches zero or critically low level and if it is remembered, parts may be reordered. Automating reordering process is necessary to be activated in the used inventory software to have the maintenance spare parts in the right time, of course after determining reorder levels for the critical parts using software

bought somewhere, or using the less accurate manually leveling A F S R system used in the industrial complex.

Store room security is represented in different aspects; store room should be well locked up**.** Store keepers always in the place, items must be taken in presence of them, these picked items must be recorded to have inventory level is really updated.

4.3 New Cost Effective Alternatives For Old Electric Equipments

4.3.1 Soft Starters

When the induction motor starts up, it draws high current, known as inrush current; it is four to ten times the motor full load operation current. Also induction motor produces severe starting torque pulsations which cause shocks to the driven equipment and the mechanical system components damage (Nithin, Jos, & Rafeek, 2013). Instead of using a traditional motor starters such as star delta starters that limit the inrush current only by ($1/\sqrt{3}$) factor, the use of electronic based soft starter equipment allows ramping up the applied voltage to the motor overtime, limiting the inrush current and power, thereby reducing heat buildup significantly and extending lifetime of the motor (Mukare, 2010). This advantage importance of using soft starter drastically increases if the motor is needed to be frequently turned ON and OFF, thereby saving money without being worry about excessive winding heat and damage.

A lot of motors in AL-Abiad Mine are candidates to be connected to soft starters as they are frequently turned ON and OFF, particularly in between two shift times or at sudden rise in loads. Instead of leaving them running continuously or running with no load, they can be turned OFF at these times, saving money and energy and avoiding power factor reduction caused by under loaded motors at these times.

4.3.2 Variable Speed Drives

As most of the motors operate at part load most of the time, the accumulated energy saving or the corresponding financial benefit resulted by varying the motor speed to meet that partial load, may be substantial over a prolonged period of time, at some applications a VSD can reduce energy consumption of a motor by as much as 60% (John, Mohandas, & Rajappan, 2013).

This study believes that the 90 KW motors are candidates to use electronic variable speed drives VSDs as speed controllers.

According to John et al., (2013), using VSD can reduce energy consumption by as much as 60% due to the fact that controlling the speed is by varying the frequency and therefore the supplied power.

Beneficiation unit is running 17 hours a day in average, the annual working hours are 6120. Assuming that they are 70% loaded, the five 90

KW motors (450 KW) consume 1927,800 KWH annually; JPMC pays approximately 501228 JD annually (0.26 JD/KWH). If VSDs are used, 60 percent savings (300736.8 JD) will be achieved annually only by using VSD controllers for these five motors as shown in Fig 4.13.

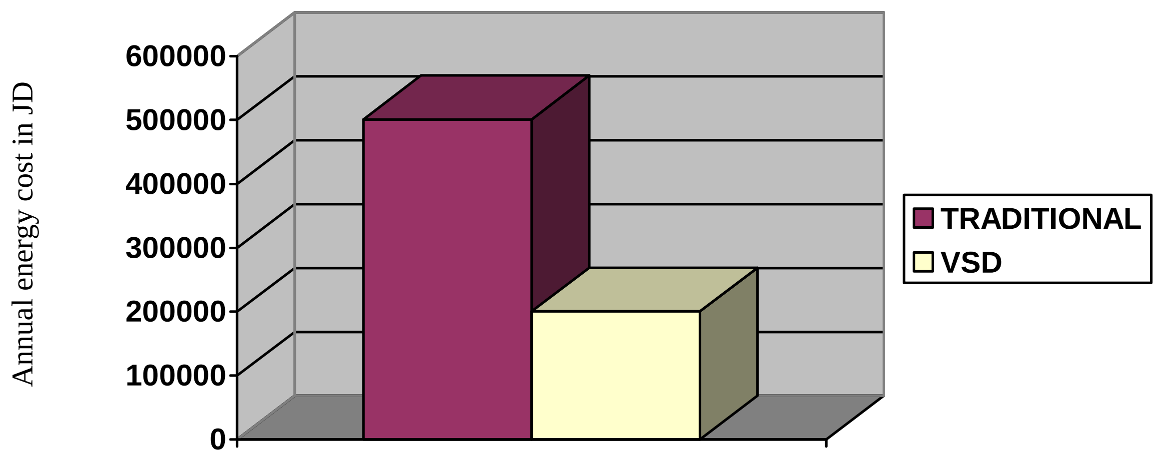

Figure 4.13
Energy saving in JD by using 5 VSDs with 5(90 KW) motors

Other savings may be achieved by using VSDs. Reducing maintenance costs because these drives gradually ramp the motor up to the required or suitable operating speed which lessen the stress in electrical and mechanical parts, increasing the life of the motor and the driven mechanical equipment (Bhukya & Basak, 2014). Among the many other benefits of VSDs is maintaining the PF near to unity without using expensive capacitors and savings associated with decreasing the reactive power usage and reducing the regarding losses (Dave, Mokariya, & Patel, 2013) and deleting penalties that may required by the electric utilities.

Benefits also may include reducing vibration problems, equipment slow wear due to less heat and stress on all the rotating parts, including bearings (Mathakari, Mhatre, & Pawar, 2012), based on costs resulted because of traditional speed variation use and presented in table 3.6, these costs could be cut as a result of VSD installing as seen in fig. 4.14.

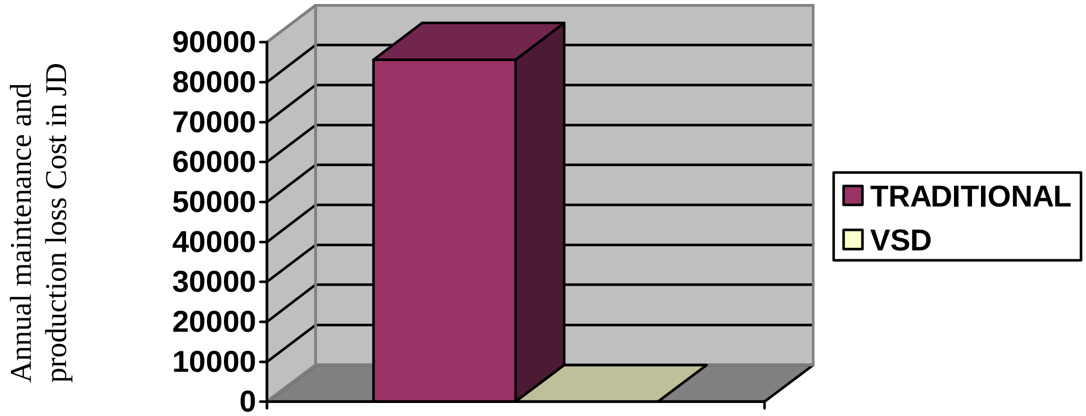

Figure 4.14
Maintenance and production loss Cost reduction in JD by using 5 VSDs with 5(90 KW) motors.

4.3.3 Lighting

It is the responsibility of electrical maintenance to keep indoor and outdoor lighting in Wadi AL-Abiad Mine facilities running in the required quality with minimum maintenance and operation costs. While the lighting system and technology used and its installations are outdated and inefficient, there are new technologies use less energy, have less maintenance efforts and costs, and have a great impact on the employee's productivity and comfort.

In addition to the great opportunities of energy saving, improving illumination, increasing consumer's satisfaction that new lighting solutions can offer, it is possible to reduce the CO_2 emission (Silva, Lopez, Fontaina, & Diaz, 2013).

To understand the type of savings gained by upgrading to new technologies, it is enough to say that efficient lighting could be achieved by replacement of high power consumption lighting with energy efficient lighting systems, which can offer significant energy and cost savings (D. Jain & Kaur, 2013). Also these systems can reduce maintenance costs by offering more life span lamps (Zhu & Raison, 2014).

To be more convincing, the following bulb comparison chart in table 4.11 is explaining the differences between many traditional lamps including the widely used T-8 fluorescent lamps and other technologies including the LED technology, this comparison fixes 2600 Lumen as a target lumen and taking life span of one light source as reference (which is LED), it is clear that 1 LED lamp instead of 5-T8 Fluorescent lamps (Dixit, Pathak, & Sudhakar, 2015).

Table 4.11
Bulbs comparison chart

Lamp	Burning hours	Lumen	Watt	NO. of required bulbs
Incandescent	1200	2600	150	42
CFL	8000	2600	50	6
T8	10000	2500	36	5
LED	50000	2600	25	1

Section 321 of Energy Independence And Security Act (EISA, 2007) in USA sets maximum wattages and minimum rated average life spans for different incandescent lamps to reduce light bulbs usage of energy by 25 percent starting in 2012 and to encourage phase out of the inefficient lamps and lighting systems**.**

A tremendous energy savings of 50% are resulting by replacing fluorescent lighting with LED, LED is capable of giving the same light output as fluorescent with lesser wattage tube, CO_2 emissions is cut down by 50%, other savings related to no mercury contents in LED lighting, and the number of LED tubes required to replace has reduced by 30% (Devibala.B, Karuppusami, Rajalingam.P, & Jha, 2013).

Concerning LED lighting as the most energy saving solution, 50% average saving, having 1500 fluorescent lamps, each consumes 40 watt and 8 Hrs daily operation:

Power consumption = Lamps quantity*power*Hours*days number (1)

1500*40*8*360 = 175200 KWH (2)

Electricity price for industrial facilities in Jordan is 0.26 JD/ KWH

0.26 * 175200 = 45552 JD Annual (3)

Fixing new led technology can cut the bill by 50% at average.

0.50 * 45552 = 22776 JD Annually savings. (4)

The resulted savings are presented in fig. 4.15 below.

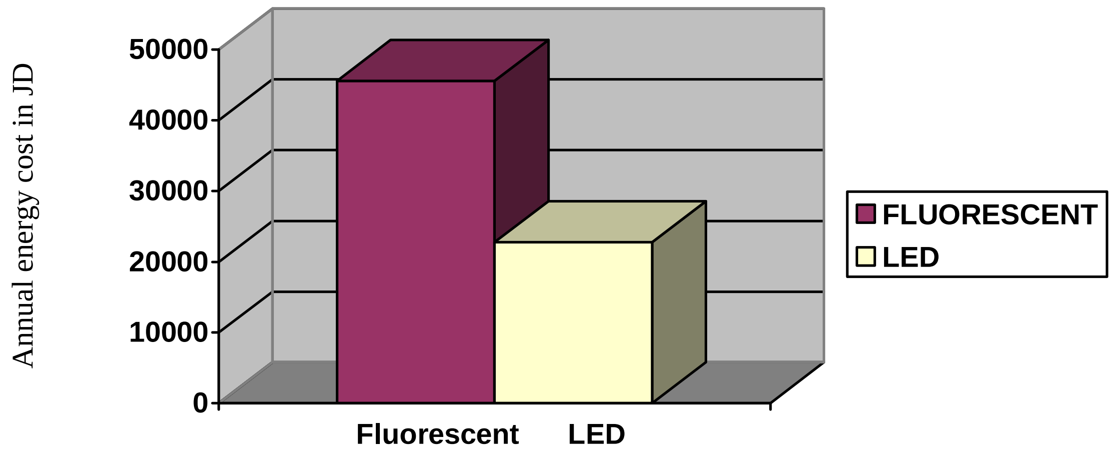

Figure 4.15
Cost reductions JD by using LED lighting technology instead of Fluorescent lamps for indoor lighting

These savings will be added to the future savings resulted from longer life free of maintenance and replacement costs, also other savings may be added if the number of installed LED lamps is reduced because of the capability of giving the same light output as fluorescent with lesser wattage lamp enough Lumen that is obtained by less LED lamps compared to the fluorescent lamps.

More savings may be obtained by control of lighting, most of the offices lights should not be turned ON after 4:00 PM, and more than 5000 JD annually can be saved at the administration building only by using timers to turn these offices off at 4:00 PM.

Installing timers to turn 1000 lights off while rooms are unpopulated for 16 hours period could save energy costs of 56190 JD that consumed during this period along the year; this saving is presented in fig. 4.16.

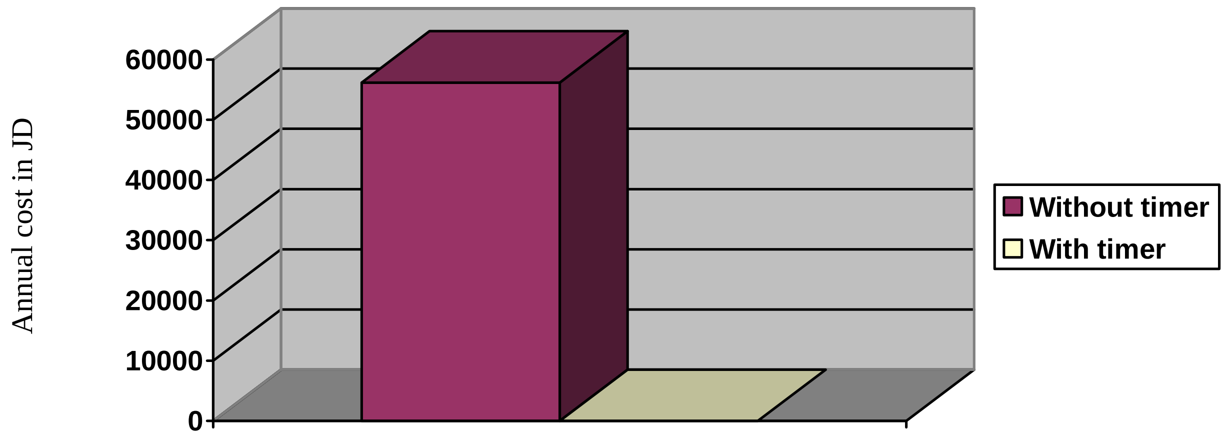

Figure 4.16
Yearly Energy saving and Cost reductions in JD by using timers to turn 1000 lamps off for 16 hours daily when rooms not used.

Outdoor lighting in AL-Abiad Mine also can be replaced by LED technology which can provide significant energy savings and maintenance reductions compared to the existing traditional used systems. Also using timers or photo cells instead of breakers, and installing photo cells at the places where none of lighting control systems are used. All of these modifications could save energy and reduce the costs as shown in fig 4.17.

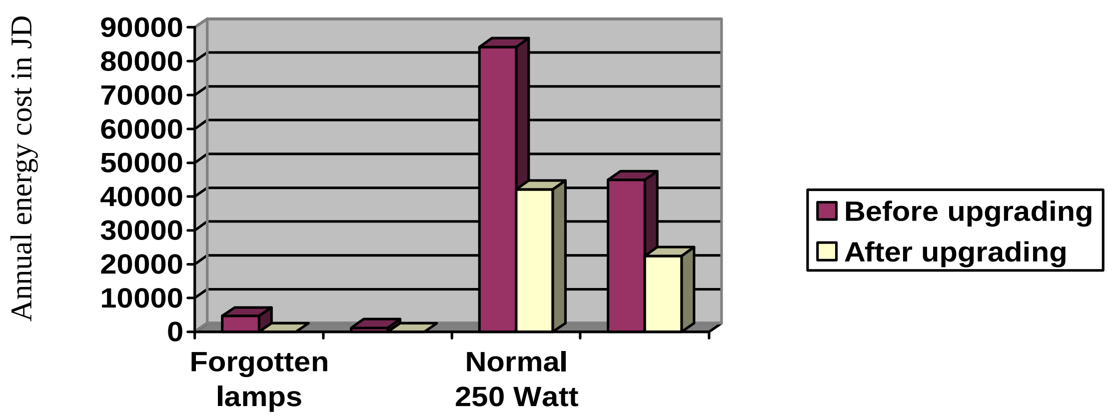

Figure 4.17
Yearly Energy saving and Cost reductions in JD by using LED outdoor lamps and photocells.

Beside the benefits of LED for indoor and outdoor uses, security that LED technology can offer by its high illumination and reliability make it as a good investment for outdoor uses.

4.4 Electrical Maintenance Cost Effective Practices

4.4.1 - Power Factor Correction (PF)

PF is a measure of electrical power efficiency; it is given by the ratio of active power consumed by the facility load to apparent power delivered to the load. Hence, there is necessity to improve the energy efficiency by minimizing the transmission and distribution loss in the electric grid (Abd Allah, 2014)**.** If power factor is less than one it means that excess power is needed to perform the actual work.

PF correction can be obtained by installing capacitor banks to generate locally the needed reactive energy for the transfer of electrical useful power, allows a better and more rational technical-economical management of the facilities (Bhattacharyya, Choudhury, & Jariwala, 2011). These capacitors also can be installed with the option of controller that measures the actual operation power and connect the needed quantity of capacitors to keep PF as set in the controller, hence avoiding excess reactive power resulted by connecting more than needed capacitors. Other practice that can be applied to improve PF is by increasing induction motors load from no load to full load (Khanchi & Garg, 2013). Motors' running with no load is one of the reasons to lower PF in AL-Abiad mine. Motor repairing quality has high role in improving PF besides replacing the under loaded motors with lower rate motors (Bhukya & Basak, 2014).

Other benefit may be obtained by improving the power factor is reducing the main withdrawn current allowing more expected future loads to be fixed without incurring the cost of higher rating transformer (Bhukya & Basak, 2014). Reducing overloading of cables, transformers, and switchgear is an important benefit obtained by PF correction (Al-Naseem & Adi, 2011).

Other advantages of power factor improvement which can be obtained by employing proper power factor correction scheme are: Efficiency increasing and less greenhouse gases due to reduction of power consumption, reduction of electricity bills, more KVA available from the same existing supply or transformer, reduction of I^2R losses in transformers and the facility distribution equipment (Sarkar & Hiwase, 2015).

PF in AL-Abiad Mine ranges between 0.79 and 0.86, which is considered low. Hence, the power factor of the mine electric grid can be corrected by addition of capacitors; the total annual penalty that is due to power factor during the recent 12 months is 15,480 JD. This penalty may be increased and repeated if the PF continues to reduce. By adding the appropriate capacitors, the charged amount will be avoided with an average total cost of 10500 JD. The payback period will be less than 1 year. Savings that could be gained are presented in fig. 4.18.

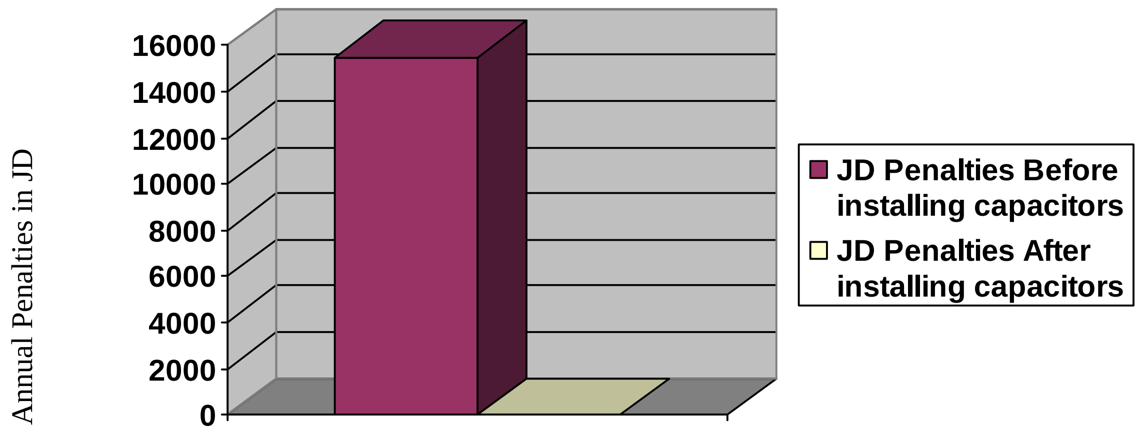

Figure 4.18
Yearly JD penalties avoiding by installing Capacitors.

4.4.2 - Resizing Motors

An oversized or under loaded induction motor presents low power factor and efficiency, varying with applied loads, low load motor resizing, gives the opportunity for a rapid return of investment, even when accounting for mechanical adaptation and initial costs, the motor power factor is improved and unnecessary expenses on corrective capacitor installation are avoided (E. S. Ramos, Tatizawa, & G. Ramos, 2013).

Operating an AC induction motor at less than full – load conditions leads it to consume more energy than it needs to perform its work (Razali, Abd Alla, Choudhury, & Khan, 2008).

Motors running at loads less than 30 % of their full rate power are not efficient (Ashtekar & Dhole, 2015), high energy savings can be gained by replacing them with proper sizes.

Using MOTOR MASTER (2011) Software gives the results of replacing the under loaded motors listed in table 3.9 by smaller sizes, these results include the savings of energy and the related JD as presented in table 4.12. Yearly energy savings and related JD savings due to resizing motors are shown in fig. 4.19 and fig. 4.20 respectively.

Table 4.12
Energy saving and costs reduction due to motors resizing.

Unit	Existing size KW	Suggested size KW	No. of motors	Energy saving KW/year	Saving JD/year
Beneficiation	7.5	5.5	3	7770	2067
Beneficiation	11	7.5	2	2436	648
Crushers	18.5	15	1	4906	1305
Beneficiation	45	22	4	15444	4108
Crushers	11	7.5	3	3654	972
Dryer 4	240	160	1	9605	2554

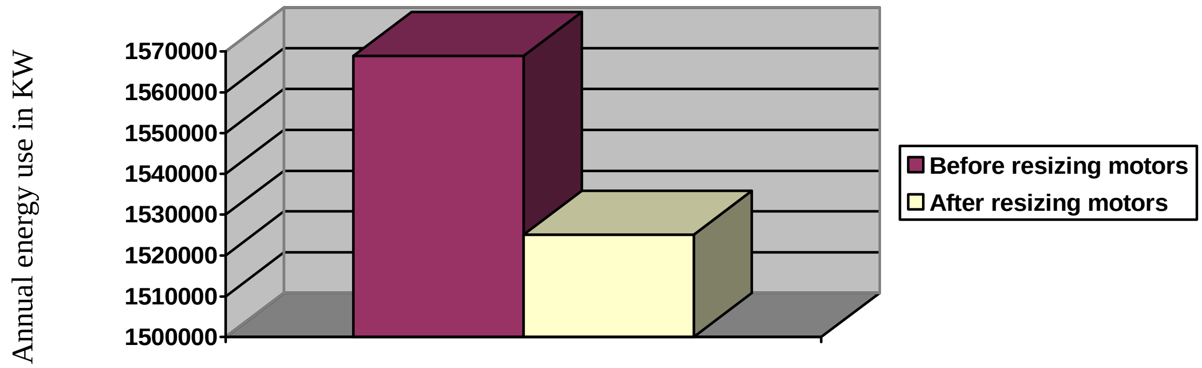

Figure 4.19
Yearly energy savings by resizing motors.

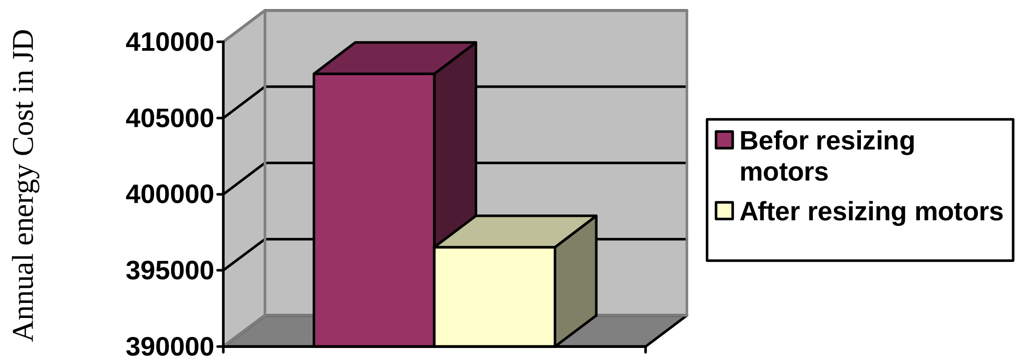

Figure 4.20
Yearly Cost reductions by resizing motors.

4.4.3 Motors Repair And Replace Guide

Because electrical motor is the core of the electrical system, as it includes rotating parts, it is exposed to failures more frequently than other electrical equipment. Facilities and maintenance departments should have a guide for making a decision to repair the failed motor or replace it.

Having such guide is a very good maintenance practice, it may lead to save money, and these savings emerge over the preceding two decades when the new high efficiency motors become available in the market as a possible choice to replace the failed one. Efficiency is also an important factor when the failed motor needs rewinding. A rewound motor is typically less efficient than a new one, the loss of efficiency is due to the age and degradation of the failed motor, or as a result of the rewind process, each time a motor is rewound it loses 1% to 5% of its efficiency for each rewinding process (Al-Ghandoor & Al-Hinti, 2007).

A generation ago the decision to repair the motor was taken if its repair or rewinding cost value is a percentage of the new motor cost plus

time to be in service; The rule of percentage may no longer fit due to many associated factors that complicate the decision to repair or replace as set by The Electrical Apparatus Service Association (EASA, 2001).

A guide suggested by EASA (2001) can be used as a support in AL-Abiad mine motor workshop as given in figure (4.21).

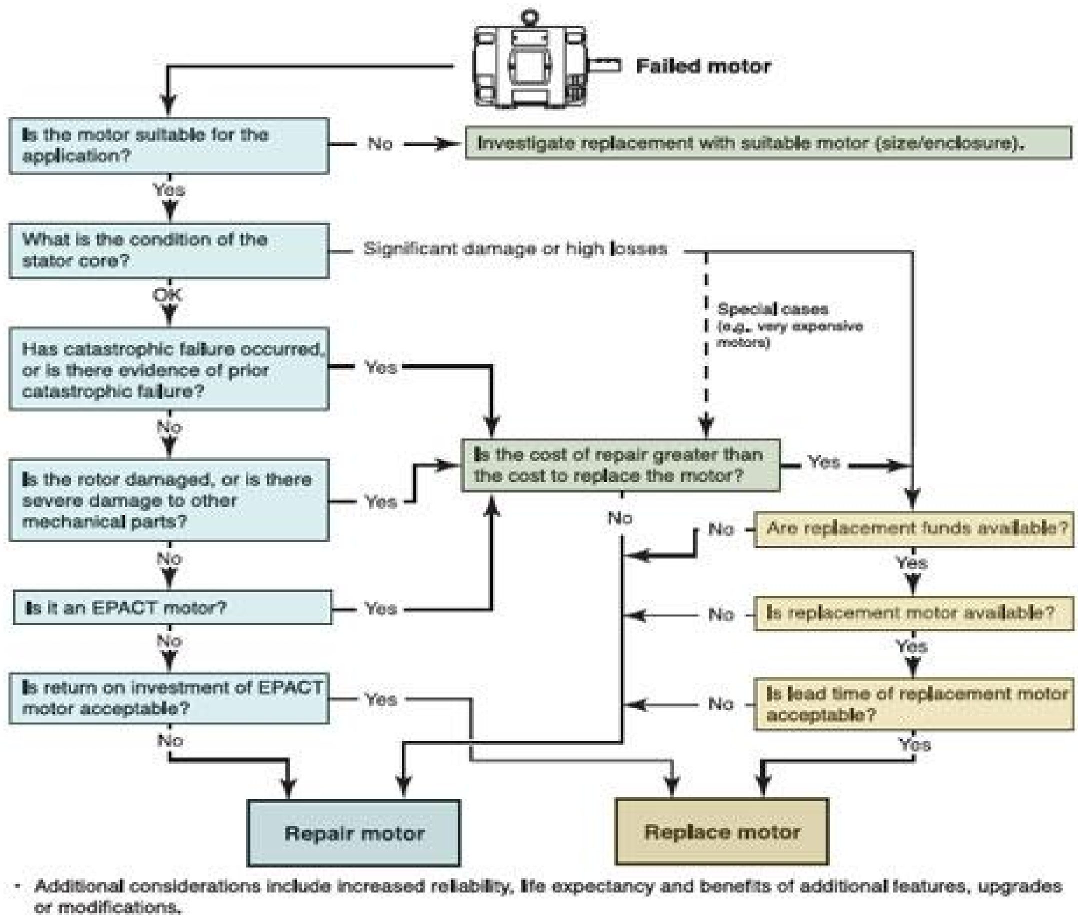

Fig 4.21

Failed motor repair/replace decision flow chart. Source: EASA (2001)

The significant savings gained after replacing the failed standard efficiency motors by new energy efficient or NEMA premium efficiency motors are resulted because of the high energy tariff in Jordan which is 0.26 JD /KWH.

4.4.4 Measurement instrumentations and control systems

"The developments of microprocessor or computer-based instrumentation that can be used to monitor the operating condition of plant equipment, machinery, and systems have provided the means to manage the maintenance operation" (Mobley, 2004, p.2).

Because of running without instruments and sensors the probability of incurring high maintenance costs may increase and equipment insurance coverage for major equipments may be lost in case of accident. Measurement instruments, indicators, recorders, alarm systems are always used as guides to lead to the failures causes, paying attention to an imminent problem or failure, so specific operation procedures may be followed to stop or mitigate the problem consequences.

If temperature probes are installed to protect large motor that listed in table 3.8 significant savings could be obtained by preventing production stop losses and cost of maintenance or rewinding as presented in fig. 4.22.

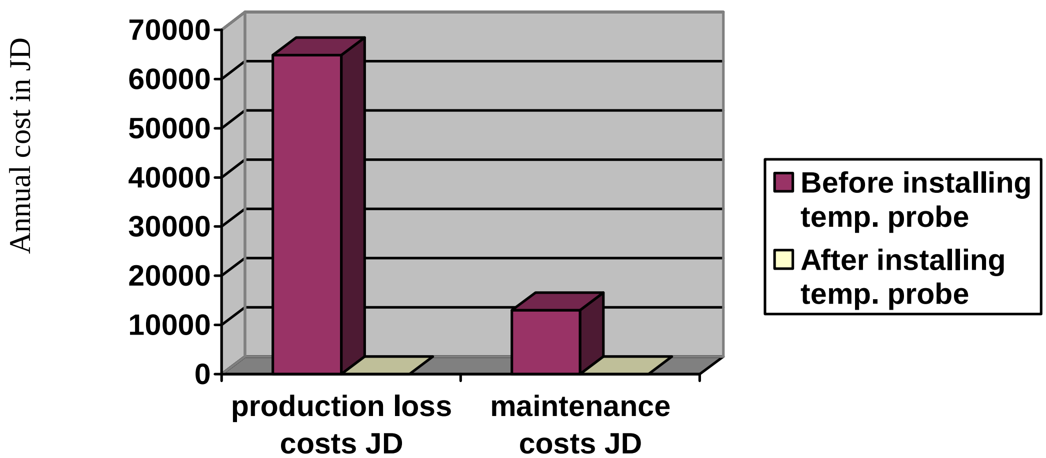

Fig. 4.22
Annual cost savings in JD due to installing temperature probes to selected large motors.

To obtain the advantages of the interlocking control system that was cancelled and put out of service in AL-Abiad Mine, this system can be replaced and retrofitted by Programmable logic controllers PLCs which already were designed to replace relay logic systems, PLCs are designed to withstand severe and harsh conditions (such as dust, moisture, heat, cold etc) (S. Vosough & A. Vosough, 2011) .Using PLC, small cabinet can equipped with hundreds of inputs and outputs, while the hardware relays that occupied large space are replaced by software instructions saved in small electronic chips.

4.5 Specifications

4.5.1 - Ingress protection (IP)

The international protection rating or ingress protection rating is a two digits code used to define equipment protection level, the code includes the prefix IP followed by two numbers, the first number is a measure of the protection against solids and the second is for protection against liquids.

Table 4.13 below explains some of these codes (British Standard: 60529 (BS: 60529), 1992).

Table 4.13

Ingress protection description

IP	1ST numeral protection against contact and ingress of foreign bodies	2nd numeral protection against water
44	Protected against Solid foreign objects of 1mm diameter and greater	Protected against splashing water from all directions
55	Dust protected	Protected against jet of water From all directions
66	Dust tight	Protected against jet of water of similar force to heavy seas

Dust and phosphate particles that enter inside motors will cause damage for the internal components. Dust particles will cause electric short circuits if they coincide with moisture. These particles also may block cooling path contributing to overheating. Thus selecting the right level of protection can assist in withstanding the related conditions. Also dust particles, in case of humid environment, increase the opportunity of electrical contact failures (Jinchun & Gang, 2012).

Motors in the mine have IP 55 code which means they are not protected completely against dust, and protected only against low pressure water jets from any direction. This study believes that protection code for crushers and dryers' motors should be IP 64 and IP 66 at beneficiation unit because labors are used to use water jets for cleaning purposes which expose these motors for hazard. Significant cost reduction could be obtained by choosing proper IP class for the motors listed in table 3.5; this reduction is shown in fig.4.23.

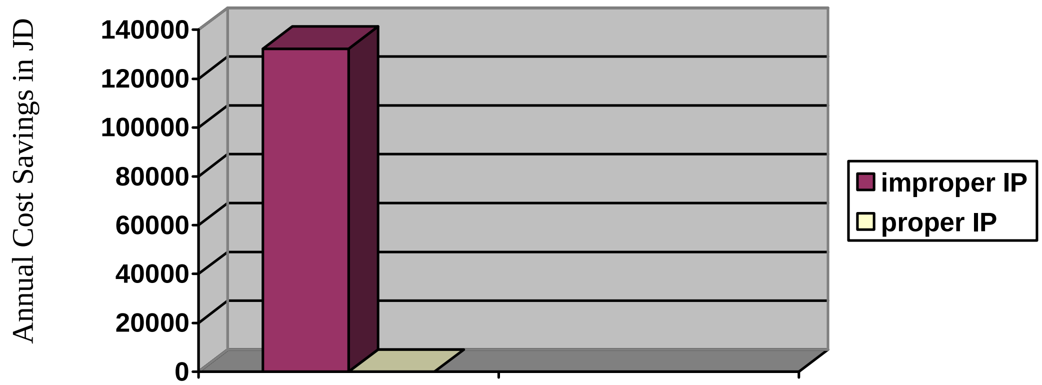

Fig. 4.23
Annual cost savings in JD due to choosing proper IP for the selected motors.

Purchasing motors of suitable enclosure with slightly higher prices compared to the high maintenance and rewinding cost due to unsuitable enclosure seems to be feasible. Also downtime and production loss as a result of motor failure makes sense for investment in more protection and suitable enclosures. This applies not only for electric motors but also for the majority of the electric equipment.

4.5.2 - Energy Efficient Motors (EEM)

The improved design, the better technique and materials included in manufacturing the energy efficient electric motors lead to reduce energy losses (Bhukya & Basak, 2014). These motors usually designed to have longer insulation and bearing lives, lower waste heat output, less vibration, and increased reliability, as a result EEM can achieve more efficiency by reducing 3- 6% of the energy losses through the motor. (Lipu & Karim, 2013).

To evaluate the economical benefits of implementing EEM in AL-Abiad Mine, it should be noted that their prices are higher than the standard efficient motors by 21 to 35 percent, the following graph below in fig. 4.24 shows the difference between efficient and standard motors prices obtained from motor manufacturer representative in Jordan.

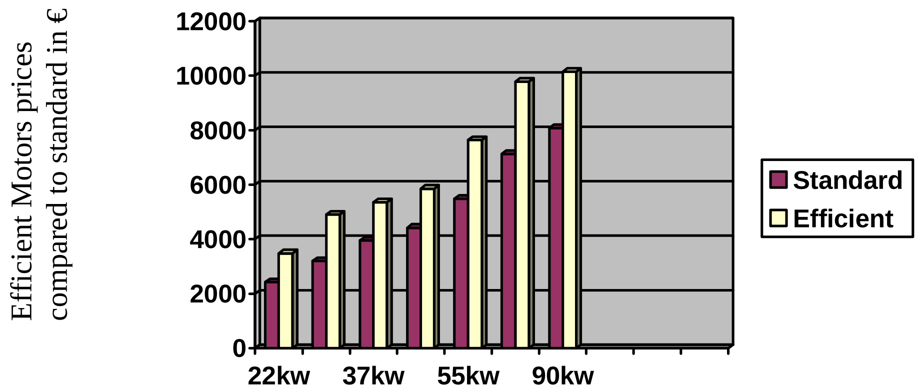

Fig.4.24
Manufacturer prices for Efficient and standard different motor sizes in the EU(€).

Motors in AL-Abiad Mine are frequently rewound; some of motors are repaired and rewound many times since they have been put in service in 1979, the study believes that the average current operating efficiency of these motors is 85%. The low efficiency is justified because of rewinding these motors each time they fail instead of purchasing and fixing high efficiency motor.

Due to age and degradation, old motor looses part of its efficiency. Also because of frequent rewinding process, motor efficiency loss ranges from 1% to 5% for each time it is rewound (Al-Ghandoor & Al-Hinti, 2007).

Motor Master (2011) Software also can be used to compare the savings obtained by rewinding the standard efficient motor and the replacing by new premium efficient motor. Motor Master is much more precise software developed by the U.S Department of Energy's (DOE's) Office of Industrial Technologies and contains data of from many motor manufacturers, such as prices, efficiencies, and there are choices for efficiency, load percent, energy price, and the demand charge. Replacing the selected old standard motors by high efficiency motors could result annual savings as shown in table 4.15. Energy cost reduction is presented in fig. 4.25.

Table 4.14
Motors chosen to be replaced with higher efficiency ones.

Motor	Kilowatt	Number	Savings JD/year	payback period	Old cost
Over flow, Under flow	45	8	24248	N/A	440216
Filter	90	5	31570	0 .85	562500
Pusher filter	55	5	17255	1.03	343750
Crusher M4	110	2	13644	1.09	275000
Belts to silo	75	2	10192	0.92	187500
Dryer 1, 2, 4	75	3	15288	0.92	281250
Fan	160	2	25596	N/A	400000
Fan Dryer 4	240	1	19317	0.55	312500
Sum	2240 KW		157160		2802716

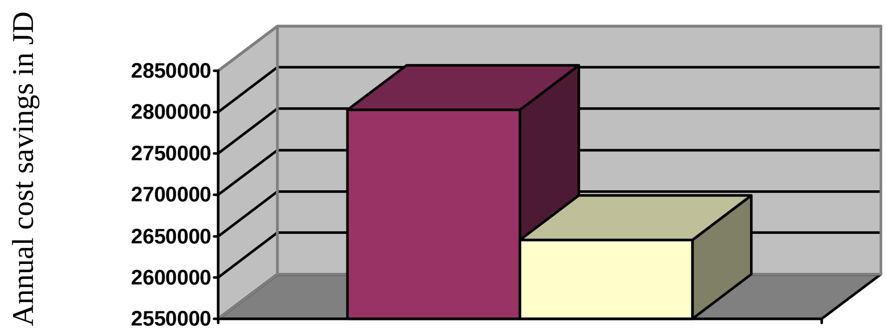

Figure 4.25
Yearly energy cost saving in JD by using higher efficient motors.

4.5.3 Power Line Insulators

The mine is electrically fed by 33 KV, 20 Km power line; this line is equipped with porcelain and glass insulators. The dusty environment with the existing of rain water or moisture and pollution expose them to degradation of their withstand voltage properties (Gencoglu, 2007), forming one of the main failure causes to these types of insulators, leading to possible power outage and production stopping.

Other suggested type of insulators can be used is a polymer material or composite insulators which have lighter weight, longer life, better electrical and mechanical properties, better performance in the existing desert heavy dust especially at the time of wet conditions. Continuous substantial improvements on the design and manufacturing of this insulator type will bring down their production and installation cost (Gencoglu, 2007).

This may be a suitable technical solution in Al-Abiad Mine to prolong the operating life of these insulators, reduce the possible breakdowns, reduce the maintenance costs including replacing the line insulators and machines deterioration as a result of the sudden main power shutdown.

Using distilled water to wash power line insulators along the power line is very efficient way to clean these insulators and protect them from the impact of the different environmental conditions. Equipment that used to wash insulators is expensive; rental of this equipment is a suitable manner.

Using insulators of polymer material and following periodic check, cleaning and replacing the defected ones could prevent related power failures, saving costs of production loss as shown in fig. 4.26, added to the other hidden technical costs represented by the sudden turning equipments OFF and ON.

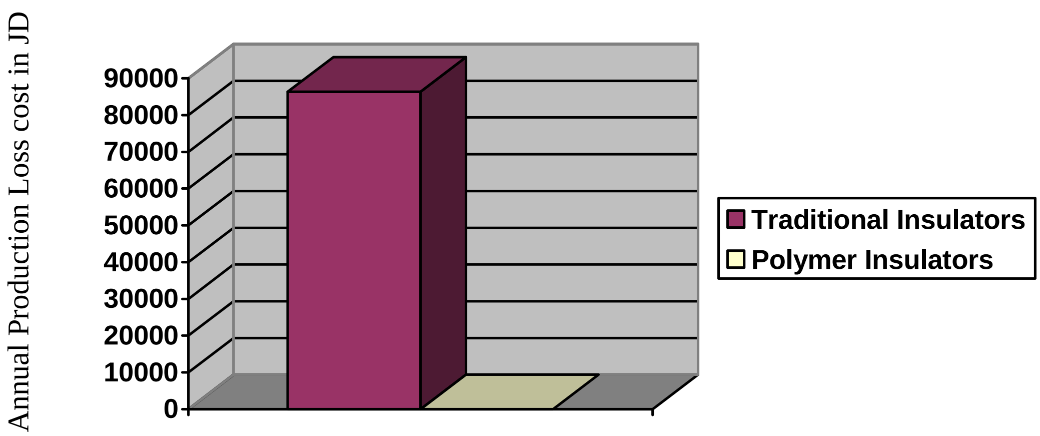

Figure 4.26
Yearly production loss saving and Cost reductions in JD by using better insulators type and implementing preventive maintenance.

4.6 Power Quality And Continuity

Any power disturbance such as power outage or voltage sag/swell can result in equipment malfunction; productivity reduction and data loss. Hence, power quality and power continuity are important factors that should be ensured for critical applications (Prasanna & Sreedhar, 2014).

Personal computers are subjected to the power quality; malfunctions may include power supply, screen, key board, software, and data loss. AC contactors and relays also subjected to voltage interruptions (Khalid & Dwivedi, 2011).

Grounding is one of the most important aspects of the electrical system, it is necessary to differentiate the functions of the grounded

conductor (neutral) from the equipment grounding (safety ground), also wiring of the electrical system should be checked for loose or improper connections, power disturbances in the form of voltage fluctuations and noise are common present in the electrical system and maybe very harmful to the electronic equipment, these disturbances include transients, sags, swells, over voltages, under voltages, harmonics, outages, frequency variations and high frequency noise (Rojin, 2013).

Methods that may be used to improve power quality include the following: Proper designing of the Load equipment and power supply system, application of suitable harmonic filters, application of voltage compensators, connecting uninterruptible power supplies (UPSs), and standby power sources (Khalid & Dwivedi, 2011).

There are different ways to enhance power quality problems in AL-Abiad Mine power system network. Using Distribution Static Compensator (D-STATCOM) is one way to enhance voltage sags/swell; harmonic distortion and low power factor. D-STATCOM is based on injecting current into the system to mitigate the voltage sags/swell, to correct low power factor, and improve harmonic distortion (Vishwakarma & Saxena, 2014).

If power quality issues are processed, savings in direct maintenance costs due to defected equipments are presented in fig. 4.27.

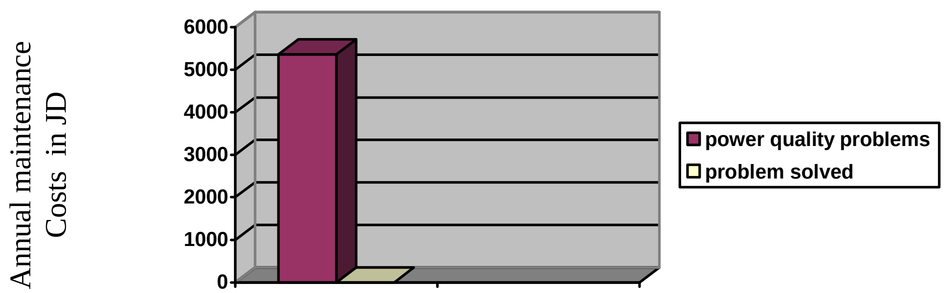

Figure 4.27
Yearly maintenance Cost reductions in JD by processing power quality problems.

Some units in the mine are not connected to the emergency electricity generator, the study believe that bridge scale unit including computers and lighting is a critical equipment, where power interruptions should not be permitted due to the possible incurred costs because of phosphate supply delay as an input material for fertilizers plant in Aqaba, or penalties resulted because of supplying ships delay in case of phosphate exporting. Connecting Un interruptible power supply UPS is a good solution to keep this equipment smoothly connected to electric power and

continue to supply phosphate in case of power failure where the emergency generator is far a way.

To address and investigate the power quality effects in AL-Abiad mine power system it is necessary to perform electrical measurements and tests that may be not possible by the electrical maintenance team. Help of NEPCO as power supplier or other consultant is justified to make decisions about proper technical solutions to mitigate the direct losses in the form of downtime and equipment failures or hidden effects that may cause significant economical losses in the form of equipment degradation.

4.7 Questionnaire

4.7.1 Questionnaire Content and Sample Size

The objective of this study questionnaire is to discuss the extent of adopting maintenance practices as per the international standards and the effectiveness of using new technologies to reduce maintenance costs in AL-Abiad Mine. Empirical data were collected by conducting a field survey on the mine employees, the questionnaire is shown in Appendix III, and it is divided into four sections.

The first section contains personal information. The second section contains twenty six questions to discuss “the extent of adopting maintenance practices according to the international standards in the field of maintenance management” from the perspective of employees. The third section includes eleven questions to discuss "The effectiveness of using computers in maintenance management compared to the pioneers in this area" from the perspective of employees. The fourth section contains sixteen questions to explain “extent of effectively adopting the best maintenance practices in terms of maintenance and operation costs" from the perspective of employees.

The grading scale that used in the study follows Likert scale as in table 4.15 (Likert, 1932):

Table 4.15
Grading scale

Strongly Disagree	Disagree	Neutral	Agree	Strongly agree
1	2	3	4	5

Research methodology depends on the analysis of data using inferential analysis, which depends on distributing a questionnaire and using SPSS software.

The sample is selected using stratified random sampling by dividing population of 350 employees which is the number of the mine employees to five groups: maintenance, processing, mining, management, and warehouses. Percentage of each group in the selected sample is shown in table 4.18.

Forty five employees have been selected to be the sample size and asked to fill the questionnaire, two persons have not been responded, and three responses have been badly filled and they have been excluded.

4.7.2 Questionnaire validity

Validity has been tested by conducting the questionnaire on four maintenance engineers in AL-Abiad Mine as a trial run, their notes about some of the questionnaire words and confusing paragraphs have been taken in consideration. After modification they agreed that the questions coincide with the scope of the items and the questionnaire is valid to measure the concept of interest. The questionnaire has been evaluated by the supervisors; they amended some questions, advised to add other questions and evaluated the analyzing method.

The questionnaire also has been arbitrated by professors who have enough experience in this field and present their notes. They agreed that the questionnaire items and fields are correlated to the study subject and the questionnaire is valid to detect the required information of the study after some modifications.

4.7.3 Questionnaire reliability

Internal consistency of the study tool was extracted depending on the cronbach's Alpha, cronbach's Alpha coefficient was calculated for each field of the questionnaire, and the results are shown in table 4.16, the reliability coefficient values are high and show consistency and coherence between the paragraphs of the tool. Reliability coefficient values were in the range from 0.70 and 0.76 for the three dimensions as shown in table 4.16. Such values are acceptable for the purposes of the present study (George & Mallery, 2003).

Table 4.16
Reliability cronbach's Alpha values

Dimension	Paragraphs	Cronbach's Alpha
The extent of adopting maintenance practice according to the international standards in the field of maintenance management.	1 - 26	0.76
The effectiveness of using computers in maintenance management compared to the pioneers in this area.	27 - 37	0.70
Extent of effectively adopting the best maintenance practices in terms of maintenance and operation costs.	38 - 53	0.75

4.7.4 Results and Analysis

This section presents the questionnaire results based on the answers of each question and it includes a discussion of these results.

Based on table 4.15, the study results in terms of mean values will be judged as follows in table 4.17:

Table 4.17

Mean values ranks

Low	Middle rate	High
Less than 2.33	2.33 – 3.66	More than 3.66

So, if the value is more than 3.66, the sample conception level is high, which indicates population members approval of that phrase. But, if the mean value ranges between 2.33 and 3.66, the sample conception level is medium. While, if the mean value is less than 2.33, the conception level is low.

4.7.4.1 General variables analysis.

The following table shows the distribution of the study sample based on the general variables given in section one of the questionnaire.

Table 4.18

Distribution of sample members according to the study variables

variable	category	number	Percentage %
Department	maintenance	30	75.0
	mining	3	7.5
	processing	3	7.5
	management	2	5.0
	Warehouse & purchasing	2	5.0
Total		**40**	**100%**
Certificate	BCs and above	22	55.0
	Diploma	4	10.0
	Secondary	13	32.5
	Below secondary	1	2.5
Total		**40**	**100%**
Job	Technician	3	7.5
	Supervisor	10	25.0
	Head of Division	10	25.0
	Head of section	13	32.5
	Manager assistant	3	7.5
	Manager	1	2.5
Total		**40**	**100%**
Experience	Less than 5 years	2	5.0
	5-10 years	3	7.5
	10-20 years	1	2.5
	15-20 years	21	52.5
	More than 20 years	13	32.5
Total		**40**	**100%**
Age	20-30 years	4	10.0
	30-40 years	11	27.5
	40-50 years	21	52.5
	50-60 years	4	10.0
Total		**40**	**100%**

4.7.4.2- The second section.

The result of the second section: "The extent of following maintenance practice according to the international standards in the field of maintenance management" came as in the following table.

Table 4.19

Means and standard deviations for individual perspective of the study sample.

No.	Question	Mean	SD	Level
1.	There is a periodic preventive maintenance schedule to check the mine equipments.	3.4750	.98	Midrate
2.	Equipments have preventive maintenance procedures as per the international standards, the manufacturer recommendations and precisely followed.	3.2250	.97	Midrate
3.	After failure correction, failure is analyzed to identify the root cause.	3.5000	.816	Midrate
4.	Temperature and vibration instruments are used to analyze equipment conditions and detect any imminent problems.	3.2000	1.13	Midrate
5.	Periodic meetings are held to discuss maintenance obstacles.	3.1500	1.09	Midrate
6.	Maintenance work order form with failure full description is available and used.	3.1000	1.21	Midrate
7.	Maintenance work permit is issued by production sections in case of failure for safety of labors and equipments.	3.1250	1.15	Midrate
8.	Work hours and spare parts used in maintenance jobs are recorded for cost calculation purposes.	3.4750	1.08	Midrate
9.	Critical equipment failures, times, and maintenance costs are recorded.	3.00	.96	Midrate
10	Maintenance activities are planned and scheduled to completely use work force working hours.	3.20	.99	Midrate
11	Annual maintenance budget is prepared containing the critical jobs.	3.27	1.19	Midrate
12	All equipments have historical record containing maintenance activities along the equipment working life time.	3.15	1.05	Midrate
13	Maintenance jobs are performed in the optimum way with the least costs.	3.67	1.04	High
14	There are assigned persons for maintenance works planning and scheduling.	3.10	1.17	Midrate
15	Deferred maintenance works are recorded and followed up.	2.97	1.14	Midrate
16	House keeping is an important part and performed after completing the mine maintenance works.	3.45	1.03	Midrate

No.	Question	Mean	SD	Level
17	Emergency works form little percent of the daily maintenance activities.	3.52	1.01	Midrate
18	Mine maintenance and production sections have determined duties at the time of joint works to prevent conflicts.	3.67	.91	High
19	Training system is continuously followed to develop maintenance personnel skills.	2.47	1.03	Midrate
20	Every maintenance job has full description containing the required duties.	3.05	1.23	Midrate
21	There is a list of skills and requirements for each maintenance job.	2.85	1.09	Midrate
22	There is a system to control spare parts supplying and storing.	3.50	.96	Midrate
23	Annual check for spare parts inventory is performed effectively.	3.67	1.20	High
24	Spare parts are stored in suitable conditions.	3.35	1.21	Midrate
25	Spare parts are not urgently purchased.	3.27	.93	Midrate
26	Work places in workshops are suitable in terms of space to perform maintenance works.	3.47	.96	Midrate
	Total	**3.26**	**1.012**	**Midrate**

Table 4.19 showed that, the individual perspective of study sample for the extent of maintenance practices according to the international standards came in middle rate degree, with mean value of (3.26) and standard deviation value of (1.012), where paragraphs (13) and (18) and (23) came at the first rank with mean value of (3.67), while paragraphs (19) came at the last rank with mean value of (2.47).

The results indicate that mean values for the members conception in AL-Abiad mine toward practicing maintenance management as per the international standards were in medium degree with mean value of 3.26. This medium level is not considered as positive indication, it indicates that maintenance department needs to work strongly toward maintenance management practices as per the international standards.

Reasons to work without effectively following the maintenance standards:

1) Successive Mine managements look for different maintenance management practices as excess works that have no value.
2) Absence of experience continuity from the old and skilled personnel to the new employees.
3) Employee work culture, the lack of belief in systematic work that requires more procedures.
4) Shortage of maintenance workers.

5) Lack of training and absence of knowledge about others in this field. And absence of attending courses and conferences about maintenance management.

4.7.4.3- The third section

The result of the second question: "The effectiveness of using computers in maintenance management compared to the pioneers in this area", came as in the following table.

Table 4.20

Means and standard deviations for perspective individual of study sample.

No.	**question**	**Means**	**SD**	**Level**
27.	Equipments technical history records are available on computers.	2.77	.99	Midrate
28.	Computers are used to record Man-Hour for equipments maintenance works.	2.62	1.10	Midrate
29.	Measuring maintenance labors productivity using data on computers	2.55	1.10	Midrate
30.	Failures root causes are documented and saved in computers to be used when needed.	2.60	.98	Midrate
31.	Spare parts used in maintenance are documented in computers.	3.00	1.03	Midrate
32.	Costs of maintenance works can be determined by information in computers.	3.07	1.11	Midrate
33.	In case of technical problem, a detailed work order can be issued using computer to be executed by the assigned maintenance section.	2.42	1.03	Midrate
34.	Planning and scheduling of maintenance works can be performed using computers to benefit from the available resources.	2.62	1.16	Midrate
35.	Spare parts can be managed using computers.	3.25	1.29	Midrate
36.	Through computer, maintenance personnel can easily identify spare parts inventory.	3.10	1.27	Midrate
37.	Maintenance and spare parts information are exchanged on the local computer network.	2.65	1.21	Midrate
	Total	**2.78**	**1.13**	**Midrate**

Table 4.20 showed that, the individual perspective of study sample for effectiveness of the use of computers in maintenance management compared to the pioneers in this area came in middle rate degree, with mean value of (2.78) and standard deviation value of (1.13), where

paragraphs (35) came at the first rank with mean value of (3.25), while paragraphs (33) came at the last rank with mean of (2.42).

The results indicate that mean value for the members conception in AL-Abiad Mine towards using computers effectively in maintenance compared to pioneers in this field was in medium degree with mean value of 2.78 which indicates that maintenance department needs to work in accelerated steps to use computer and software in maintenance management activities, taking in account that computers are available and can be easily connected to local network, computerized maintenance management system can be designed and developed by the company programmers or can be purchased from the market.

Reasons that explain not using computerized systems in effective way are:

1. Mine and Company upper management lack of well to adopt computer effectively in this field.
2. Lack of awareness of Mine Engineers about computerized maintenance systems benefits.

4.7.4.4 The fourth section.

The result of the third question: “extent of effectively adopting the best maintenance practices in terms of maintenance and operation costs", came as in the following table.

Table 4.21

Means and standard deviations for individual perspective of study sample.

No.	question	Means	SD	Level
38.	Work space is suitable to perform maintenance works in time.	3.55	1.01	Midrate
39.	Mine electric motors speed is controlled as needed to save energy.	3.05	.93	Midrate
40.	Electric motors speed is controlled according to the operational need to prolong the motor working life.	3.02	.99	Midrate
41.	Proper sizes of motors are installed to control costs of purchasing and operation.	3.32	.94	Midrate
42.	In case of production stopping, motors are shutdown to reduce energy waste.	3.57	1.00	Midrate
43.	Old and expensive equipments that became out of the manufacturer production lines and have obsolete spares are usually replaced with new alternatives.	3.22	.99	Midrate
44.	Equipments are repaired while purchasing new ones is more cost effective.	3.45	1.06	Midrate
45.	Technical specifications are the most important in the decision to buy equipment and spare parts.	3.77	.86	High
46.	Equipments are purchased with specifications suitable to the operational and environmental conditions to prolong its work life.	3.55	1.03	Midrate
47.	Warehouse is arranged and organized in order not to delay maintenance works.	3.52	.96	Midrate
48.	The decision to buy equipment and spare parts based on price.	3.40	1.05	Midrate
49.	Protection devices are installed on equipment and belts for the safety of personnel and equipment.	3.32	1.02	Midrate
50.	Alarming and monitoring devices are installed in the control rooms to prevent failures before they occur.	3.00	1.19	Midrate
51.	Energy saving lighting system is	2.55	1.17	Midrate
52.	Turning off the external lighting technique used during the day.	3.07	1.22	Midrate
53.	Turning off the room and office lighting while they are not occupied.	2.75	1.08	Midrate
	Total	**3.25**	**1.01**	**Midrate**

Table 4.21 showed that, the individual perspective of study sample for the extent of effectively adopting the best maintenance practices in terms of

maintenance and operating costs came in middle rate degree with mean value of (3.25) and standard deviation value of (1.13), where paragraphs (45) came at first rank with mean value of (3.77), while paragraphs (51) came at the last rank with mean value of (2.55).

The results indicate that mean value for the members conception in AL-Abiad Mine towards adopting maintenance best practices effectively in terms of maintenance and operation costs was in medium degree with mean value of 3.25 which indicates that maintenance department needs to work in accelerated steps to follow more cost effective maintenance practices. Reasons for not highly succeed in adopting more cost effective maintenance practices are:

I. Lack of knowledge about new and modern cost effective alternatives of equipments.
II. Absence of attendance more equipment exhibitions.
III. Upper management lack of concerning on energy management and power saving alternatives.

4.7.4.5 Hypothesis test

Hypothesis 1:

It is assumed that there is no reduction in maintenance cost based on the present weak use of international maintenance standards in Al- Abiad mine.

Firstly, correlation factor between the two variables, international standards and maintenance cost reduction has been extracted, Table below shows the result.

Table (4.22)

Correlation between International standards following and Maintenance cost reduction

Variables	Present International standards following
Maintenance cost reduction	0.07

Table 4.22 shows correlation value of 0.07 which indicates a very weak positive significant value relation. This should excite the maintenance department in Al- Abiad mine to adopt more international maintenance standards to reduce maintenance costs.

To test the hypothesis, simple regression analysis has been used; Table 4.23 shows the model summary.

Table 4.23

Simple Regression between the extent of following maintenance international standards and maintenance cost

R	R^2	T	Sig.
0.070	0.005	0.261	0.798

$\alpha = 0.05$*

Table 4.23 shows that the T-value was (0.261) while T from tables is 2.02 and significance is (0.798), R^2 which is defined as the amount of variability in the data explained by the regression model is 0.005. Using T test which is the student test as given in statistics , there are no significant differences at ($\alpha \leq 0.05$) between the extent of following maintenance international standards and maintenance cost reduction, while the present following of the international maintenance standards variable explains only (0.5 %) from change in maintenance cost reduction variable as represented by R^2 . So, hypothesis 1 is accepted.

Hypothesis 2:

It is assumed that the present use of computer techniques at the present time in AL- Abiad Mine is the cause of non reduced maintenance cost.

Correlation factor between the two variables, using computer techniques in maintenance and maintenance cost reduction has been extracted, Table below shows the result.

Table 4.24

Correlation between using computer techniques and Maintenance cost reduction

Variables	using computer techniques
Maintenance cost reduction	0.276

Table 4.24 shows correlation value of 0.276 which indicates low positive significant value relation. This should also excite the maintenance department in Al- Abiad Mine to improve using computer techniques for maintenance costs reduction purposes.

To test the hypothesis, simple regression analysis has been used; Table 4.25 shows the model summary.

Table 4.25

Simple Regression between using computers in maintenance and maintenance cost

R	R^2	T	Sig.
0.276	0.076	0.861	0.412

$\alpha = 0.05$*

Table 4.25 shows that the T-value was (0.861) while T from tables is 2.02 and significance was (0.412), R^2 is 0.076. the result of using T test is that there are no significant differences at ($\alpha \leq 0.05$) between the use of

computer techniques in maintenance and maintenance cost reduction, while using computer in maintenance explains (7.6%) from change in maintenance cost reduction. So, hypothesis 2 is accepted.

Chapter Five
Conclusions and Recommendations

5.1 Conclusions

This study presents hereunder the following conclusions:

1- Preventive maintenance is absent inside maintenance department in general and electrical maintenance in particular. Also there is a clear shortage in maintenance force.

2- Equipments have no recorded history whether in the form of paper records or electronic and maintenance activities data are not documented, whether these data is related to spare parts, man-hours, or completed maintenance job details. As a result maintenance budget is difficult to be expected.

3- Most often, Failure root causes are not investigated and analyzed. Maintenance meetings to discuss bottlenecks or negotiate the near future plans mostly are not held. Specialized maintenance training courses are rarely done. The possibility of the same malfunction reoccurrence is great with doubled costs. Maintenance at the moment behaves in reactive manner.

4- Maintenance jobs are performed after oral work order, maintenance is considered as service or production support facility. Now days maintenance has integral relation to production side.

5- Spare parts inventory is not well controlled; spares are not stored in good conditions.

6- Computer and maintenance software are not used in maintenance activities planning; scheduling, work orders and spare parts inventory control. If it is introduced in maintenance works, it could reduce the maintenance costs.

7- Alternative equipments, systems, and practices can save 928135 JD annual costs.

8- The present following of international maintenance standards in Al-Abiad mine has weak effect in maintenance cost reduction. Following the international maintenance standards effectively will reduce maintenance costs.

9- The present use of computer techniques in maintenance has low effect in reducing maintenance cost at AL-Abiad mine. Using computer maintenance software such as the proposed one in this study will strongly contribute in reducing maintenance costs.

5.2 Recommendations

1- Adopting preventive maintenance scenario for the electrical equipments in parallel with the followed corrective maintenance policy, preventive maintenance should be implemented as per the international standards.
2- Taking the decision to replace the existing equipments by the new cost effective alternatives.
3- Starting to follow the good maintenance practices which are adopted by the first class companies.
4- Giving energy saving more concern as it became an attractive area for maintenance specialists to reduce maintenance and production costs.
5- Introducing the use of computerized maintenance management system CMMS in maintenance activities, using CMMS could help in increasing the maintenance efficiency, and reducing maintenance costs. A suggested CMMS for preventive maintenance is presented in chapter 4 and appendix II.

5.3 Proposed Future Work.

1- Investigating the impact of human factor on maintenance cost reduction.
2- Maintenance planning and scheduling using comprehensive computerized maintenance management system CMMS.

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Appendix (I)
(Electric Equipment Preventive Maintenance Procedures)

Appendix I

(Electric Equipment Preventive Maintenance Procedures)

Substation	**Inspection for**	**NFPA 70B Action**	**Periodicity**
Insulators	-Contaminated surfaces. -Physical damage. -Evidence of violent corona when substation is energized using Ultrasonic detector.	-Cleaning -Replacing	12M
Conductors	Evidence of overheating at bolted joints using Infrared. -Checking for tightness of bolts connection while power OFF. -Aluminum to copper joints for evidence of corrosion, overheating or looseness	Tightening -Tightening -Repairing and tightening Without overstress the bolts.	12M
Air disconnecting switch	-Insulators and conductors checking as above -Inter phase linkages and operating rods are not bent or distorted and that all fastening are secure -The switch is mechanically locked in a closed position	-As above -Repair or replace	12M
Substation	**Inspection for**	**NFPA 70B+ BBC Manual**	**Periodicity**
Power operated switch	-Periodical check for proper mechanism And control function -Limit switch adjustment -Relays for poor contacts, burnt out coils and inadequate supply voltage -Switch contacts alignment, pressure Burns or corrosion. -Arcing horns inspection for burning -Insulation for cracks breaks, burns, Deposits and dust. -Gear box for moisture and corrosion -Operating handle grounding slip ring Contacts for corrosion, wear, and Breaking. -Safety interlock checking for proper operation.	-Servicing or replacing -Smoothing by clean, fine Sand paper, or replacing -Replacing -Replacing or cleaning -Replacing	12M
Grounding equipment	-Station, enclosure, apparatus grounding for tightness and absence of corrosion.		12M
Enclosure	-Fences security -Gates and doors proper operation		12M

Substation Part	Inspection for	NFPA 70B Action	Periodicity
Miscellaneous equipment	-The availability and condition of rack-out devices, hoisting or handling apparatus, grounding equipment, hot sticks, rubber gloves and test equipment. -Operation of flood lights, transformer cooling fans checking. -Any warning lights of temperature gauges, pressure gauges, level gauges.	 - Repairing and replacing	3M 12M 6M
Switch gear Assemblies	**Inspection for**	**NFPA 70B Action**	**Periodicity**
Bus risers Insulation Enclosure Doors and access panels	-Partial inspection -Inspection for not accessible areas -Exposure to moisture and air contaminants outside. -All hardware is in place and has good condition.	 -Keep it clean, keep it dry	12M 12M 12M
Hings, locks and latches Ventilation openings Out door of switch gear enclosure Internal surface	-Lubrication -Screens coverings fit in place -Roof or wall for leakage -Rust or water marks -Base for openings -Moisture due to condensation and atmosphere humidity or water pools -Signs of previous moisture at internal surfaces such as dust patterns and rust -Ventilation good condition, clear of obstructions, air filters are clear.	 -Caulked or grouted -Floor openings should be sealed -All openings around cables at entrance ducts should be sealed by an electrical grade of caulking compound. -Water pools elimination -Heat and air circulation	12M 3M 6M 6M
Lighting and house keeping Insulation	-Interior and exterior proper operation -Availability of spare equipment and handling devices check -Spare equipment and handling do not hamper normal operation or block ventilation -Moisture combined with dirt		3M 12M

Electrical distress	-Surfaces of the insulating Members before cleaning Dust and after cleaning -Inspection at boundaries Insulators, between insulators And ground structure and at the Insulators surface in the form of Corona erosion markings	-The formed white powdery Deposits on the insulators Are wiped off as recommended by Manufacturer. -Bolts heads, sharp projections Should be properly insulated And shielded.	12M
Tracking	-Streamers or sputter arcs on the surface of insulation, usually near high voltage electrodes. -Irregular carbon lines in the shape of tree branches	-Cleaning the surface	12M
Thermal damage	-Heating (hot spots) -Loosely bolted connections in a bus bar splice or void spaces. -Signs of damaging heat such as discoloration, cracking, flaking of varnish coatings, embrittlement of cable insulation, melting	-Replacing damaged insulating material. -Loose bolts tightening	12M
Oil circuit breaker	**Inspection for**	**Action**	**Periodicity**
-Insulating bushings	-Evidence of damage -Surface contamination	-Replacing -Cleaning	12M
-Oil	-Detection of moisture, carbon and sludge -Insulating value - Dielectric breakdown test (by sample as covered in ASTM D 877)	-Reconditioned and retested -Replaced Oil recommended by the manufacturer only, and tested before use. Avoiding Aeration when oil replacing.	12M
-Contacts	-Contacts resistance measurement -Contacts erosion or pitting -Contact pressure and alignment -Looseness of bolted connections and springs	- Cleaning or replacing -After fault current interruption, contacts should be	12M

		extensively maintained.	
-Arc-Quenching Assemblies	-Carbon deposits or other surface contamination	-Cleaning	12M
-Operating mechanism	-Loose or broken parts	- Replacing or tightening	12M
	-Missing cotter pins or Retaining keepers	- Replacing	
	-Missing nuts and bolts	-Replacing	
	-Binding, excessive wear	-Adjustment for wear in Certain parts. -Replacement in others	
	-Inspection for quick and positive closing and tripping action without binding, slow action, delay, failing to trip.	-Correction before returning To service.	
-Breaker auxiliary devices	-Oil level gauge, sight glass, valves, gaskets, oil lines, tank lifters, breathers	-Breaker should be taken out of service if the oil level gauge indicates lower level.	12M
	-Closing motor or solenoid, shunt trip, auxiliary switches, bell alarm switch inspection for proper operation, insulation condition, and tightness of connection.	-Maintaining	
	Proper operation of : -ON/OFF indicators -Spring charge indicators -Mechanical and electrical interlocks -Key Interlocks, padlocking fixtures -Positive interlock feature.	-Mechanical component lubrication if needed.	
	-Protective relay circuits - manually checked by closing the Contacts to trip the circuit breaker. - each relay removed from its case For inspection and cleaning. - Inspection for loose screws. - friction in moving parts - iron filings between the induction disk and the permanent magnet - distress with the relay.	-Breaker put in the test position. -Isolated for testing while the electrical system is in normal operation. -Fine silver contacts cleaned with a burnishing tool. -One relay is removed at a time so as not to totally disable the protection. -Prescribed settings should be applied.	
-Interrupter	-As in the air circuit breaker	-Mostly can be easily	12M

switch -Auxiliary equipment	-Interrupter device -Surge arrestors checked for evidence of damage to the porcelain housing or surface contamination	Removed from the Switch and cleaned. -Replaced or cleaned	 12M
lead acid battery	**Inspection for**	**FIST action**	**Periodicity**
-Float voltage -Specific gravity -Temperature	-Visual inspection -Battery float voltage -Accuracy of charger meter -Pilot cells float voltage -All cells float voltage -Specific gravity for pilot cells -Specific gravity(10% of all cells) -Specific gravity for all cells -Temperature for pilot cells -Temperature for 10% of cells -Temperature for all cells - Temperature of ambient And pilot cells -Room temperature -Electrolyte level -Connection resistance -Capacity test -Safety equipment inspection	- Keep batteries clean -Battery terminal voltage =2.23V/Cell -Pilot cells voltage -Rated S.G of electrolyte Is 1.24 at +20C and at MAX electrolyte level If needed, top up with purified water in accordance with DIN 43530, part 4.	6M 1Year 6M 1Year 1Year 1Year 1Year
Battery charger	**Inspection for**	**Reclamation standard action**	**periodicity**
	Checking the charger for Holding the load -Checking float and equalize Charge setting -Checking the enclosure -Checking the integrity connection	-Maintaining - Cleaning	6 Months

Capacitors	Inspection for	NFPA 70B action	Periodicity
-Insulating bushing Connections -Capacitor case -Fuses of capacitors Ventilation	-dirt or corrosion -Leak bulges -Discoloration -Blown fuses -Obstructions at Ventilation openings in Capacitor housing	-Cleaning -Should be discharged before handling or making connections by closing the ground devices. -Replacing -Replacing -Fuses should not be removed by hand until the capacitors has been discharged. -Removing	6 M 3 M 6 M 3M 3M
Protective relays, meters and instruments	**Inspection for**	**NFPA 70B action**	**Periodicity**
-Protective relay	-Moving parts are free Of friction or binding -Wiring loose connections -Contacts pitting or erosion -Solenoid coils or armatures Overheating -Glass cracks or damage -Friction in moving parts -Iron filing between the Induction disk and the Permanent magnet -Any distress with the Relay -Fine silver contacts checking	 -Removing from its Case for inspection and Cleaning -Can be isolated for testing While the electrical system In normal operation -Relay settings apply	6M 6M
Interlocks and safety devices	**Inspection for**	**NFPA 70B action**	**Periodicity**
-Key interlocks System -Grounding	Operation checking -Mechanical interlocks should prevent withdrawal of circuit breaker in the closed position.	-Adjustment -Checking	6M 6M

Switch	-Safety shutters should automatically cover the stab-in ports. -Limit switches should prevent over travel of motorized lifting devices. -Proper sequence -System lubrication -Instruction posting	-Checking -Checking and maintenance -Checking	6M 6M 6M
-Grounding switch	-Protecting from rust	-Checking	6M
Grounding	**Inspection for**	**NFPA70B action**	**Periodicity**
-Terminal connections -Bonding jumpers Metal raceway .Couplings .Bushings .Set-screws .Locknuts -Ground fault Indication	-Tight and free of corrosion -Physical abuse and broken strands -Tight and properly seated -Checking lamps and wiring	-Tightening and cleaning -Replacing -Retightening - Servicing and replacing	6M
Air circuit breakers	**Inspection for**	**NFPA70B action**	**Periodicity**
- General -Insulation	- Proper function by manual operation -Contaminations -Signs of corona, tracking, or thermal damage -Overheating, discoloration, deposits, smoothness and good alignment.	- Adjustment should be made in accordance with the manufacturers recommendations -Interphase barriers should be removed and cleaned along with all other insulating surfaces with vacuum cleaner -Cleaning insulating materials with solvents -Correcting cause of heating -Replacing insulating materials if needed -Keep it clean, keep it dry -Deposits removing with alcohol or a silver cleaner, smoothing, or	6M

-Contacts	 -Slight impressions on the stationary contacts.	replacing. -Keeping pressure normal as per the manufacturer recommendations.	
Arc interrupters	-Removing and examined -Humidity -Dirt, residue, arc products -Large broken or cracked ceramic parts, erosion of ceramics. -Splitter plates erosion.	-Replacing -Dried -Removed with cloth or light sanding, dirt removed with vacuuming. -Broken ceramic stacks renewal. -Replacing splitter plates.	
-Operating mechanism	-Loose or broken parts -Missing cotter pins -Retaining keepers -Missing nuts and bolts -Binding or excessive wear. -Binding, slow action, delay in operation, or failure to trip or latch	-Adjustments for wear in certain parts, or replacing other parts. -Correction prior to returning to service. -Keep it SNUG and keep it FRICTION FREE.	
Breaker auxiliary devices	-Correct operation insulation condition and tightness of connections. -ON/OFF indicators, spring- change indicators, interlocks proper operation. -Protective relay circuits checking. -Trip devices tested for proper operation	-Maintenance, connections tightening. -Lubrication -By closing the breaker in the test position and manually closing the contacts of each protective relay to trip the circuit breaker. -Calibration as per the manufacturer recommendations.	
Power and distribution transformers	**Inspection for**	**NFPA70B action**	**Periodicity**
Readings	-Load current observation at peak load -Voltage readings at peak load (over under voltage) -Temperature gauge readings and recording (overloaded)	-If higher than the rated Full-load value steps to reduce the load should be taken -Correction	12 M

Connections Insulators and insulating surfaces Gasket bases Pressure relief devices Tank, cooling fins, tap changer, gaskets And openings Tank grounding electrode Bucholtz relays Conservator tank Insulating oil Special oil tests	-Liquid level gauge checking especially after Long low load period -Signs of overheating and corrosion -Tracking, cracks, or chipped skirts -Leak -Leak, corrosion, diaphragm crack -Leaks, deposits of dirt, corrosion -Corrosion or loose connections -A grounding electrode resistance test -Inspection regularly as per manufacturer instructions -Inspected and tested as per manufacturer instructions -Contamination or impairment -Humidity -Acid -Acidity, color, power factor, interfacial tension, level of PCBs	-Correction -level adding -Cleaning from contaminations and replacing damaged insulators -Leak repairing -Cracked diaphragm replacing -Leak repair, dirt cleaning Corrosion cleaning and painting -Repairing, tightening. -Filtering, replacing or adding after applying dielectric breakdown test -Special humidity control steps should be taken -Reclaiming by chemical and absorbent means	12M 12M 12M 12M 12M 12M 12M 12M 24M
Power cables	**Inspection for**	**NFPA70B action**	**Periodicity**
Visual inspection -Manholes cables	-Sharp bends -Physical damage -Excessive tension -Oil leaks -Pits -Cable movement	-Adjustment -Joints or replacing -Cleaning -Maintenance -Correcting -Renewal	6M 12M

	-Insulation swelling -Soft spots -Cracked jackets -Damaged fire proofing -Poor ground connections -Deterioration of metallic sheath bonding -Support corrosion and Weak -Continuity of main Grounding systems -Terminations and splices Soft spots, tracking, or Signs of corona -Ground braids corrosion And tight connections -Cable bottom surface wear And scraping		
-Manholes	-Spalling concrete or deterioration of the aboveground portion -Water existence -Identification tags or marking	-Cleaning and maintenance -Water pumping -maintenance or renewal	12M
Aerial installations	-Mechanical damage due to vibration -Deteriorating supports -Suspension systems -Cable insulation, bending, abrading, pinching at the dead end supports	-Maintenance and cause correcting -Maintenance and renewal	12M
-Raceway installations	-Raceway deterioration Or mechanical damage -Joints looseness or corrosion	-Correcting and maintenance -Repairing -Renewal	12M
Motor control equipment	**Inspection for**	**NFPA70B action**	**Periodicity**
Enclosures Exterior	-Excessive dust and Dirt contamination -Corrosive conditions -Grease, oil, rust -Mechanical damage -Condition of gaskets	-Cleaning by rags free of lint or removing by vacuum cleaner During shutdown -Cleaned and refinished or replaced -Cleaning by suitable solvents -Repairing or replacing -Replacing as needed	3M
Interior of enclosure	-As in exterior -Excessive vibration and loosened bolts	-Tightening	3M

	-Condensation -Falling debris -Ventilation passage for obstruction	-Cleaning and closing the door -Removing -Cleaning	
Bus bar, wiring, terminal connections	-Loose and overheating or discoloration -Vibration	-Tightening to suitable torque -Tightening	6M
-Bus bar support insulators	-Free of contamination -Cracks, arc tracking	-Cleaning -Replacing	6M
-Power and control wiring	-Insulation overheating -Conductor damage -Temporary wiring	-Replaced and re- routed Or shielded -Removing or replacing by permanent wiring	6M
-Disconnects	-Damage -Contacts welding or pitting -Mechanism operation properly	-Replacing -Repairing or replacing -Operating manually -Lubrication	6M
-Contactors	-Excessive burning -Beads of molten material -Contact face erosion -Arc chute erosion or breaking -Dust	-Replacing of all contacts Simultaneously -Replacing the contactor -Replacing -Removing by vacuum cleaner or wiping by light brush	6M
-Thermal overload	-Checking for loose terminal or heater connection, overheating and carbonization -Tested with primary injection current	-Tightening or replacing -Calibration or Replacing	3M
-Push buttons ,selector switches ,indicating lights ,timers, and auxiliary relays	-Loose connections -Proper mechanical operation -Burnt lamps -Inspection of exposed contacts -Signs of overheating	-Tightening -Correction -Replacing -Cleaning -Investigating, Or replacing	6M
-Mechanical interlock	-Free to operate -Bearing surfaces free to perform the intended function -Excessive wear and deformation	-Releasing -Releasing -Replacing	6M

Molded case circuit breaker MCCB	Inspection for	NPFA 70B action	Periodicity
	-Dirt and external contaminations -Structure strength and cracks -Loose connections and excessive heat -Manual operation check	-Cleaning -Replacing -Tightening to The suitable torque -Replacing	3M
Fuses rated less than 1000 V	**Inspection for**	**NFPA70B action**	**Periodicity**
-Terminals -Fuse holder -Fuse clips -Fuse	-Examined for discoloration, corrosion poor contact and overheating using Infrared. -Connections checking. -Contact pressure checking -Checking for discoloration Overheating, or corrosion -Signs of deterioration, discoloring , and case damage.	-Cause determining and Correction. -Clean corrosion with none corrosive agent. -Tightening after disconnecting power -Replacing -Correction, clean corrosion -Replacing with proper type, rating, and size.	6M 6M 6M 6M
Fuses rated over 1000 V	**Inspection for**	**NFPA70B action**	**Periodicity**
-Insulators -Contact surface -Fuse -Fuse fixing	-Inspection for breaks, cracks And burns, salt deposits, and dust -Pitting, burning, alignment, and Pressure. -Excessive erosion, fuse tube Corrosion, tracking and deterioration -Conditions of bolts, nuts, washers, Pins, terminal connectors, lock(latch).	-Cleaning, replacing after Fuse disconnection -Replacing -Replacing, cleaning -Tightening, cleaning, replacing	6M 6M 6M 6M
Motors	**Inspection for**	**NFPA70B action**	**Periodicity**
-Stator and rotor winding	-Dust and dirt, corroded parts	-Cleaning by non saline water plus detergent washer (25 PSI) followed by rinse with hot non saline water -Washed parts are dried at 85 C for 2 Hrs -Electrical insulation is	12M

		dried for 6 Hrs at 85 C and additional 4 Hrs at 105 to 12o C -Winding insulation resistance is measured every 2 hours until it stabilized -Cooling the insulation at a dry environment -Before put in service, recommended insulation resistance as per ANSI/IEEE 43 -Corroded parts repairing or replacing	
	-Moisture, oil, grease	-Cleaning with a solvent solution	
	-Winding tightness in the slots	-Varnishing and oven treatment to fill the air spaces	
	-Insulation surface cracks, crazing, Flaking, and powdering.	-Renew insulation by a coat or two Of air drying varnish.	
	-Rotor excessive heating, discoloring , cracked rotor bars, and cracked End rings	-Brazing or welding broken bars -Replacing bar	
-Ball bearings	-External inspection for heating at the time of greasing -Bearing condition check by opening bearing housing.	-Cleaning bearing and housing parts cleaning -New grease adding -Bearing replacing	12M
Lighting	**Inspection for**	**NFPA 70B action**	**Periodicity**
-Lamps, reflectors And lenses	-Dirt, dust	-Cleaning program between and through group relamping -Periodic light metering (light level) -Cleaning by wiping or washing as per luminaire manufacturer instructions	6M
	-Burnt lamp	Spot relamp as lamp fails -Or group relamping at 70% of their rated average life.	
-Sockets, hangers	-Inspection at the time of relamping	-Replacing needed parts or correction	12M
-Voltage	-Higher voltage and lower voltage	-Correction	12M

	-Fluorescent lamps blinking	-Lamp with the same Voltage, size, type, and lumen. or ballast replacing.	
UPS	**Inspection for**	**NFPA 70B action**	**Periodicity**
	- Transfer switches checking - Disconnecting means and bypass switch checking - Battery and charger inspection - Ventilation checking - Electrical connections -System alarms and indication lamps -Signs of overheating -Unusual sounds and odors. -Rectifier and inverter signs of leaking fluid from capacitors, capacitors discoloration, heat sink discoloration	-As recommended by the manufacturer -As recommended by the manufacturer - Maintaining -Air filter cleaning or replacing -Tightening -Investigation and maintaining -Visual inspection and investigating -Investigating -Capacitor replacing -Heat sink replacing or correction -Capacitors replacing	6M 6M 3M 6M 3M 3M 6M 5Years
Diesel Generator	**Inspection for**	**FIST action**	**Periodicity**
	-Emergency power standby systems EPSS Components -Generator set battery -Generator set as per PEP 28 -Transfer switch -Circuit breaker -Emergency power standby systems	-Visually -Checking and maintenance -Exercise for minimum of 30 minutes. -Electrically transferred in both directions -Manually exercised -Operation at available load for assigned Class duration or minimum of 4 hours	1 Week 1 week 1 Month 1 Month 1 Year 6 months

Appendix (II)
(Preventive Maintenance Software Codes)

Appendix II

(Preventive Maintenance Software Codes)

Main page

```
Private Sub AboutInventory_Click()
frmAbout.Show vbModal
End Sub

Private Sub AboutSystem_Click()
frmAbout.Show vbModal
End Sub

Private Sub AddNewCustomerProfile_Click()
frmCustomer.Show vbModal
End Sub

Private Sub AddNewEmployee_Click()
frmEmployee.Show vbModal
End Sub

Private Sub AddNewItem_Click()
frmEmployee.Show vbModal
End Sub

Private Sub BackUp_Click()
frmBackUp.Show vbModal
End Sub
Private Sub Exit_Click()
Dim ans
ans = MsgBox("Do you really want to terminate the system?", vbQuestion + vbYesNo)
If ans = vbYes Then
   'Unload Me
   End
   'frmSplash.Show
Else
   Exit Sub
End If


End Sub

Private Sub Image1_Click(Index As Integer)
Frame1(0).Visible = True
Frame1(1).Visible = False
Frame1(2).Visible = False
Frame1(3).Visible = False
End Sub
```

```
Private Sub Image16_Click()
AboutInventory_Click
End Sub

Private Sub Image2_Click(Index As Integer)
Frame1(0).Visible = False
Frame1(1).Visible = True
Frame1(2).Visible = False
Frame1(3).Visible = False

End Sub

Private Sub Image3_Click(Index As Integer)
Frame1(0).Visible = False
Frame1(1).Visible = False
Frame1(2).Visible = True
Frame1(3).Visible = False

End Sub

Private Sub Image4_Click(Index As Integer)
Frame1(0).Visible = False
Frame1(1).Visible = False
Frame1(2).Visible = False
Frame1(3).Visible = True
End Sub

Private Sub img_AddNewCustomer_Click()
AddNewCustomerProfile_Click
End Sub

Private Sub img_AddNewEmployee_Click()
AddNewEmployee_Click
End Sub

Private Sub img_AddNewItemOfJewelry_Click()
NewItem_Click
End Sub

Private Sub img_AddNewJewelryItemTypes_Click()
ItemTYpes_Click
End Sub

Private Sub img_AddNewSupplier_Click()

End Sub

Private Sub img_BackUP_Click()
BackUp_Click
```

```
End Sub

Private Sub img_ChangePassword_Click()
ChangePassword_Click
End Sub

Private Sub InsertReport_Click()
Form1.Show vbModal
End Sub

Private Sub ItemTYpes_Click()
frmItemTypes.Show vbModal
End Sub
Private Sub ChangePassword_Click()
frmChangePassword.Show vbModal
End Sub

Private Sub Label1_Click(Index As Integer)
Frame1(0).Visible = True
Frame1(1).Visible = False
Frame1(2).Visible = False
Frame1(3).Visible = False
End Sub

Private Sub Label4_Click(Index As Integer)
Frame1(0).Visible = False
Frame1(1).Visible = False
Frame1(2).Visible = False
Frame1(3).Visible = True

End Sub

Private Sub MDIForm_Load()
Data1.DatabaseName = App.Path & "\CMJ.mdb"
Data1.RecordSource = "select * from Tool_Details"
Data1.Refresh
CMJ_Main.Show
CMJ_Main.Enabled = False
frmSplash.Show vbModal
Dim cn As New ADODB.Connection
Dim rs As New ADODB.Recordset
cn.ConnectionString = "Provider=Microsoft.Jet.OLEDB.4.0;Data source=" & App.Path
& "\CMJ.mdb"
cn.Open
rs.Open ("select * from Tool_Details where mintinance_date<=#" & Format(Now(),
"DD/mm/YYYY") & "#"), cn, adOpenDynamic, adLockOptimistic
Do While Not (rs.EOF)
MsgBox (rs("tool_Name"))
Set C0nw0nk = CreateObject("CDO.Message")
C0nw0nk.From = "karaklove788@gmail.com"
```

```
C0nw0nk.To = rs("mail")
C0nw0nk.Subject = "Hello"
C0nw0nk.TextBody = rs("note")
C0nw0nk.Configuration.Fields.Item("http://schemas.microsoft.com/cdo/configuration/s
mtpusessl") = True
C0nw0nk.Configuration.Fields.Item("http://schemas.microsoft.com/cdo/configuration/s
mtpauthenticate") = 1
C0nw0nk.Configuration.Fields.Item("http://schemas.microsoft.com/cdo/configuration/s
endusing") = 2
C0nw0nk.Configuration.Fields.Item("http://schemas.microsoft.com/cdo/configuration/s
mtpserver") = "smtp.gmail.com"
C0nw0nk.Configuration.Fields.Item("http://schemas.microsoft.com/cdo/configuration/s
mtpserverport") = 465
C0nw0nk.Configuration.Fields.Item("http://schemas.microsoft.com/cdo/configuration/s
endusername") = "karaklove788@gmail.com"
C0nw0nk.Configuration.Fields.Item("http://schemas.microsoft.com/cdo/configuration/s
endpassword") = "Awad@6565"
C0nw0nk.Configuration.Fields.Update
C0nw0nk.Send
rs.MoveNext
Dim Edate As Date
Dim g
Edate = Format(Now(), "DD/MM/YYYY")
g = DateAdd("d", 180, Edate)
With Data1.Recordset
.Edit
  Data1.Recordset.Fields("mintinance_date") = g
 .Update
        Data1.Refresh
End With
Loop
End Sub

Private Sub MDIForm_Unload(Cancel As Integer)
Cancel = 1
Exit_Click
End Sub

Private Sub NewItem_Click()
frmEmployee.Show vbModal
End Sub

Private Sub Picture2_Click()
Form3.Show vbModal
End Sub

Private Sub Picture3_Click()
Form4.Show vbModal
End Sub
```

```
Private Sub Picture4_Click()
Form5.Show vbModal
End Sub

Private Sub VIew_Report_Click()
Form2.Show vbModal
End Sub
```

Add report

```
Option Explicit
Dim ans
Private Sub cmdClose_Click()
Unload Me
End Sub

Private Sub Command1_Click()
Dim container1
   Data1.DatabaseName = App.Path & "\CMJ.mdb"
   Data1.RecordSource = "select * from tool order by tool_name"
   Data1.Refresh
If Text1 = "" Then
   MsgBox "Cannot save if employee name is empty.", vbExclamation, "Nickname is
missing"
   Text1.SetFocus
   Exit Sub
End If

If Text2 = "" Then
   MsgBox "Cannot save if peciece used is empty,", vbExclamation, "Firstname is
missing"
   Text2.SetFocus
   Exit Sub
End If
If Text3 = "" Then
   MsgBox "Cannot save if work hour is empty.", vbExclamation, "Lastname is
missing"
   Text3.SetFocus
   Exit Sub
End If
If MsgBox("Confirm add new Item Record.", vbQuestion + vbYesNo) = vbYes Then

   With Data1.Recordset
      .AddNew
         !tool_name = UCase(Text6.Text)
         !parts_code = Text1.Text
         !labor_cost = Text2.Text
         !total_cost = Text3.Text

         !note = Text4.Text
      .Update
   End With
```

```
    Data1.Refresh
    MsgBox "Information has been saved.", vbInformation

End If



End Sub

Private Sub Command2_Click()
  Text1.Text = ""
     Text2.Text = ""
     Text3.Text = ""
End Sub


Private Sub Command3_Click()
Unload Me
End Sub

Private Sub Form_Load()
Data1.DatabaseName = App.Path & "\CMJ.mdb"
Data1.RecordSource = "select * from tool"
Data1.Refresh
End Sub



Private Sub Frame1_DragDrop(Source As Control, X As Single, Y As Single)

End Sub

Private Sub Text3_Click()
Text3.Text = Val(Text1.Text) + Val(Text2.Text)
End Sub
```

```
View report
Option Explicit
Dim ans, rec_count, X, Y
Private Sub Combo1_Click()
With Data1
    .RecordSource = "select * from employee_Details where emp_firstname  = '" &
Combo1.Text & "'"
    .Refresh
    Text2.Text = .Recordset.Fields("cost")
    Text3.Text = Text2.Text / 1440
    Text1.Text = Val(Text1.Text) + Val(Text3.Text)
End With
End Sub

Private Sub Combo1_GotFocus()
```

```
Data1.DatabaseName = App.Path & "\CMJ.mdb"
Data1.RecordSource = "select * from employee_Details order by emp_firstname"
Data1.Refresh
Combo1.Clear
With Data1
   rec_count = .Recordset.RecordCount
   .Recordset.MoveFirst
   For X = 1 To rec_count
      Combo1.AddItem .Recordset.Fields("emp_firstname")
      .Recordset.MoveNext
   Next
End With
End Sub

Private Sub Command1_Click()
Command1.Visible = False

PrintForm
Command1.Visible = True

End Sub

Private Sub Command2_Click()
Unload Me
End Sub

Private Sub Command3_Click()
Dim cn As New ADODB.Connection
Dim rs As New ADODB.Recordset
cn.ConnectionString = "Provider=Microsoft.Jet.OLEDB.4.0;Data source=" & App.Path
& "\CMJ.mdb"
cn.Open
rs.Open ("select * from employee_Details where cost  = '" & Combo1.Text & "' &
emp_birthdate<=#" & Format(Now(), "DD-mm-YYYY") & "#"), cn, adOpenDynamic,
adLockOptimistic
Do While Not (rs.EOF)
Dim Edate As Date
Dim g
Edate = Format(Now(), "DD-mm-YYYY")
g = DateAdd("d", 30, Edate)
  Data1.DatabaseName = App.Path & "\CMJ.mdb"
    Data1.RecordSource = "select * from employee_Details"
With Data1.Recordset
       Data1.Recordset.Edit
           Data1.Recordset.Fields("emp_birthdate") = g
           Data1.Recordset.Fields("cost") = 0
           rs.MoveNext
        Data1.Recordset.Update
        Data1.Refresh
              End With
```

```
Loop

End Sub

Private Sub Form_Load()
Data1.DatabaseName = App.Path & "\CMJ.mdb"
Data1.RecordSource = "select * from employee_Details"
Data1.Refresh
'center the form:
Me.Top = (Screen.Height - Me.Height) / 2
Me.Left = (Screen.Width - Me.Width) / 2
End Sub


Private Sub ViewReport_DragDrop(Source As Control, X As Single, Y As Single)

End Sub
```

```
Form3 page
Option Explicit
Dim ans, rec_count, X, Y

Private Sub Command2_Click()
Unload Me
End Sub

Private Sub Command3_Click()
Adodc1.RecordSource = "select * from Tool_Details where Eng_name  = '" &
Text1.Text & "'"
Adodc1.Refresh
End Sub



Private Sub Form_Load()

End Sub
```

```
Form4 page
Option Explicit
Dim ans, rec_count, X, Y
Private Sub Combo1_Click()
With Data1
   .RecordSource = "select * from tool where tool_name  = '" & Combo1.Text & "'"
   .Refresh

      Text6.Text = .Recordset.Fields("note")
   End With

End Sub

Private Sub Combo1_GotFocus()
```

```
Data1.DatabaseName = App.Path & "\CMJ.mdb"
Data1.RecordSource = "select * from tool order by tool_name"
Data1.Refresh
Combo1.Clear
With Data1
   rec_count = .Recordset.RecordCount
   .Recordset.MoveFirst
   For X = 1 To rec_count
      Combo1.AddItem .Recordset.Fields("tool_name")
      .Recordset.MoveNext
   Next
End With
End Sub



Private Sub Form_Load()

End Sub
```

Form5 page

```
Option Explicit
Dim ans, rec_count, X, Y

Private Sub Combo1_Click()
With Data1
   .RecordSource = "select * from employee_Details where emp_firstname  = '" &
Combo1.Text & "'"
   .Refresh
      Text2.Text = .Recordset.Fields("cost")
   End With
End Sub

Private Sub Combo1_GotFocus()
Data1.DatabaseName = App.Path & "\CMJ.mdb"
Data1.RecordSource = "select * from employee_Details order by emp_firstname"
Data1.Refresh
Combo1.Clear
With Data1
   rec_count = .Recordset.RecordCount
   .Recordset.MoveFirst
     For X = 1 To rec_count
      Combo1.AddItem .Recordset.Fields("emp_firstname")
      .Recordset.MoveNext
   Next
End With
End Sub

Private Sub Command1_Click()
   Data1.DatabaseName = App.Path & "\CMJ.mdb"
```

```
   Data1.RecordSource = "select * from employee_Details order by emp_firstname"
   Data1.Refresh

If MsgBox("Confirm add new Item Record.", vbQuestion + vbYesNo) = vbYes Then

   With Data1.Recordset
     Data1.Recordset.Edit
         !cost = Val(Text1.Text) + Val(Text2.Text)


      Data1.Recordset.Update
      Data1.Refresh
   End With

   MsgBox "Information has been saved.", vbInformation

End If


End Sub

Private Sub Command2_Click()
Unload Me
End Sub

Private Sub Form_Load()

End Sub
```

About page

```
Option Explicit

' Reg Key Security Options...
Const READ_CONTROL = &H20000
Const KEY_QUERY_VALUE = &H1
Const KEY_SET_VALUE = &H2
Const KEY_CREATE_SUB_KEY = &H4
Const KEY_ENUMERATE_SUB_KEYS = &H8
Const KEY_NOTIFY = &H10
Const KEY_CREATE_LINK = &H20
Const KEY_ALL_ACCESS = KEY_QUERY_VALUE + KEY_SET_VALUE + _
                KEY_CREATE_SUB_KEY + KEY_ENUMERATE_SUB_KEYS + _
                KEY_NOTIFY + KEY_CREATE_LINK + READ_CONTROL

' Reg Key ROOT Types...
Const HKEY_LOCAL_MACHINE = &H80000002
Const ERROR_SUCCESS = 0
Const REG_SZ = 1                         ' Unicode nul terminated string
Const REG_DWORD = 4                      ' 32-bit number

Const gREGKEYSYSINFOLOC = "SOFTWARE\Microsoft\Shared Tools Location"
```

```
Const gREGVALSYSINFOLOC = "MSINFO"
Const gREGKEYSYSINFO = "SOFTWARE\Microsoft\Shared Tools\MSINFO"
Const gREGVALSYSINFO = "PATH"

Private Declare Function RegOpenKeyEx Lib "advapi32" Alias "RegOpenKeyExA"
(ByVal hKey As Long, ByVal lpSubKey As String, ByVal ulOptions As Long, ByVal
samDesired As Long, ByRef phkResult As Long) As Long
Private Declare Function RegQueryValueEx Lib "advapi32" Alias
"RegQueryValueExA" (ByVal hKey As Long, ByVal lpValueName As String, ByVal
lpReserved As Long, ByRef lpType As Long, ByVal lpData As String, ByRef lpcbData
As Long) As Long
Private Declare Function RegCloseKey Lib "advapi32" (ByVal hKey As Long) As
Long


Private Sub cmdSysInfo_Click()
  Call StartSysInfo
End Sub

Private Sub cmdOK_Click()
  Unload Me
End Sub

Private Sub Form_Load()
    Me.Caption = "About " & App.Title
    lblVersion.Caption = "Version " & App.Major & "." & App.Minor & "." &
App.Revision
    'lblTitle.Caption = App.Title
End Sub

Public Sub StartSysInfo()
    On Error GoTo SysInfoErr

    Dim rc As Long
    Dim SysInfoPath As String

    ' Try To Get System Info Program Path\Name From Registry...
    If GetKeyValue(HKEY_LOCAL_MACHINE, gREGKEYSYSINFO,
gREGVALSYSINFO, SysInfoPath) Then
    ' Try To Get System Info Program Path Only From Registry...
    ElseIf GetKeyValue(HKEY_LOCAL_MACHINE, gREGKEYSYSINFOLOC,
gREGVALSYSINFOLOC, SysInfoPath) Then
        ' Validate Existance Of Known 32 Bit File Version
        If (Dir(SysInfoPath & "\MSINFO32.EXE") <> "") Then
            SysInfoPath = SysInfoPath & "\MSINFO32.EXE"

        ' Error - File Can Not Be Found...
        Else
            GoTo SysInfoErr
        End If
```

```
   ' Error - Registry Entry Can Not Be Found...
   Else
      GoTo SysInfoErr
   End If

   Call Shell(SysInfoPath, vbNormalFocus)

   Exit Sub
SysInfoErr:
   MsgBox "System Information Is Unavailable At This Time", vbOKOnly
End Sub

Public Function GetKeyValue(KeyRoot As Long, KeyName As String, SubKeyRef As
String, ByRef KeyVal As String) As Boolean
   Dim i As Long                                ' Loop Counter
   Dim rc As Long                               ' Return Code
   Dim hKey As Long                             ' Handle To An Open Registry Key
   Dim hDepth As Long                           '
   Dim KeyValType As Long                       ' Data Type Of A Registry Key
   Dim tmpVal As String                         ' Tempory Storage For A Registry Key
Value
   Dim KeyValSize As Long                       ' Size Of Registry Key Variable
   '------------------------------------------------------------
   ' Open RegKey Under KeyRoot {HKEY_LOCAL_MACHINE...}
   '------------------------------------------------------------
   rc = RegOpenKeyEx(KeyRoot, KeyName, 0, KEY_ALL_ACCESS, hKey) ' Open
Registry Key

   If (rc <> ERROR_SUCCESS) Then GoTo GetKeyError        ' Handle Error...

   tmpVal = String$(1024, 0)                    ' Allocate Variable Space
   KeyValSize = 1024                            ' Mark Variable Size

   '------------------------------------------------------------
   ' Retrieve Registry Key Value...
   '------------------------------------------------------------
   rc = RegQueryValueEx(hKey, SubKeyRef, 0, _
                KeyValType, tmpVal, KeyValSize)    ' Get/Create Key Value

   If (rc <> ERROR_SUCCESS) Then GoTo GetKeyError        ' Handle Errors

   If (Asc(Mid(tmpVal, KeyValSize, 1)) = 0) Then         ' Win95 Adds Null
Terminated String...
      tmpVal = Left(tmpVal, KeyValSize - 1)            ' Null Found, Extract From String
   Else                                         ' WinNT Does NOT Null Terminate String...
      tmpVal = Left(tmpVal, KeyValSize)                ' Null Not Found, Extract String
Only
   End If
   '------------------------------------------------------------
   ' Determine Key Value Type For Conversion...
```

```
   '-----------------------------------------------------------
   Select Case KeyValType                          ' Search Data Types...
   Case REG_SZ                                  ' String Registry Key Data Type
      KeyVal = tmpVal                           ' Copy String Value
   Case REG_DWORD                                  ' Double Word Registry Key Data
Type
      For i = Len(tmpVal) To 1 Step -1                ' Convert Each Bit
         KeyVal = KeyVal + Hex(Asc(Mid(tmpVal, i, 1)))   ' Build Value Char. By Char.
      Next
      KeyVal = Format$("&h" + KeyVal)                  ' Convert Double Word To String
   End Select

   GetKeyValue = True                              ' Return Success
   rc = RegCloseKey(hKey)                            ' Close Registry Key
   Exit Function                              ' Exit

GetKeyError:      ' Cleanup After An Error Has Occured...
   KeyVal = ""                                ' Set Return Val To Empty String
   GetKeyValue = False                             ' Return Failure
   rc = RegCloseKey(hKey)                            ' Close Registry Key
End Function
```

Backup page

```
Option Explicit



Private Sub cmdSave_Click()
   'saves a back-up copy of the library system database
   On Error Resume Next
   Dim directory, Database
   'get path
   directory = dirlist.Path
   'if in root directory remove "\"
   If Right(directory, 1) = Chr(92) Then directory = Left(directory, (Len(directory) - 1))

   'write the database file to disk
   Database = FreeFile
   Open directory + "\CMJ_BackUP.mdb" For Output As Database

   Close Database
   MsgBox "The back-up file was created."
   'unload this form from memory
   'Unload Me
End Sub

Private Sub Command1_Click()
Unload Me
End Sub

Private Sub drivelist_Change()
```

```
   dirlist = drivelist
End Sub

Private Sub Form_Load()
   Me.Top = 0
   Me.Left = 0
End Sub

Private Sub Image4_Click()
Unload Me
End Sub
```

Change password

```
Private Sub cmd_cancel_Click()
Unload Me
End Sub

Private Sub cmd_ok_Click()
If UCase(Text1.Text) <> UCase(Text4.Text) Then
   MsgBox "Invalid old-password.", , "Change Password"
   Text1.SetFocus
   SendKeys "{home}" & "+{end}"
   Exit Sub
Else
   If UCase(Text2.Text) <> UCase(Text3.Text) Then
      MsgBox "Plese re-type the new password", , "Change Password"
      Text3.SetFocus
      SendKeys "{home}" & "+{end}"
      Exit Sub
   Else
      Data1.Recordset.Edit
      Data1.Recordset.Fields(0) = Text2.Text
      Data1.Recordset.Update
      Data1.Refresh
      MsgBox "Your new password has been saved.", , "Password changed"
   End If
End If

End Sub

Private Sub Form_Load()
Data1.DatabaseName = App.Path & "\CMJ.mdb"
Data1.RecordSource = "select * from tblPassword"
Data1.Refresh

End Sub
```

Employee page

```
Option Explicit
Dim ans

Private Sub cmdAdd_Click()
```

```
clear_all_fields
'frame
fra_ci(0).Enabled = True
fra_ci(1).Enabled = True
txt_Firstname.SetFocus
'controls
cmdAdd.Enabled = False
cmdSave.Enabled = True
cmdCancel.Enabled = True

End Sub

Private Sub cmdCancel_Click()
'frame
fra_ci(0).Enabled = False
fra_ci(1).Enabled = False
'controls
cmdAdd.Enabled = True
cmdSave.Enabled = False
cmdCancel.Enabled = False
clear_all_fields
End Sub

Private Sub cmdClose_Click()
Unload Me
End Sub

Private Sub cmdSave_Click()
If txt_Firstname = "" Then
   MsgBox "Cannot save if Firstname is empty.", vbExclamation, "Firstname is
missing"
   txt_Firstname.SetFocus
   Exit Sub
End If
If txt_MI = "" Then
   MsgBox "Cannot save if Middle Initial is empty.", vbExclamation, "Middle Initial is
missing"
   txt_MI.SetFocus
   Exit Sub
End If
If txt_Lastname = "" Then
   MsgBox "Cannot save if Lastname is empty.", vbExclamation, "Lastname is missing"
   txt_Lastname.SetFocus
   Exit Sub
End If
If txt_StreetAddress = "" Then
   MsgBox "Cannot save if Street Address is empty.", vbExclamation, "Street Address
is missing"
   txt_StreetAddress.SetFocus
   Exit Sub
```

```
End If
If txt_City = "" Then
   MsgBox "Cannot save if City or Town is empty.", vbExclamation, "City or Town is
missing"
   txt_City.SetFocus
   Exit Sub
End If


If txt_ContactNumber <> "" Then
   If IsNumeric(txt_ContactNumber) = False Then
      MsgBox "Invalid Contact number. Numbers only.", vbExclamation, "Invalid
contact number"
      txt_ContactNumber.SetFocus
      SendKeys "{home}" & "{end}"
      Exit Sub
   End If
End If
If txt_Birthdate = "" Then
   MsgBox "Cannot save if Birthdate is empty.", vbExclamation, "Birthdate is missing"
   txt_Birthdate.SetFocus
   Exit Sub
End If
If combo_Sex = "" Then
   MsgBox "Cannot save if Gender is empty.", vbExclamation, "Gender is missing"
   combo_Sex.SetFocus
   Exit Sub
End If

If MsgBox("Confirm save new customer record.", vbQuestion + vbYesNo) = vbYes
Then
   With Data1.Recordset
      .AddNew
         !emp_firstname = txt_Firstname.Text
         !emp_miname = txt_MI.Text
         !emp_Lastname = txt_Lastname.Text
         !street = txt_StreetAddress.Text
         !cost = txt_City.Text
         !contact = Trim(txt_ContactNumber.Text)
         !emp_birthdate = txt_Birthdate.Text
         !gender = combo_Sex.Text
         !note = txt_Remarks.Text

      .Update
   End With
   Data1.Refresh
   MsgBox "New customer record saved.", vbInformation
End If

'frame
```

```
fra_ci(0).Enabled = False
fra_ci(1).Enabled = False
'controls
cmdAdd.Enabled = True
cmdSave.Enabled = False
cmdCancel.Enabled = False
clear_all_fields
End Sub

Private Sub Form_Load()
Data1.DatabaseName = App.Path & "\CMJ.mdb"
Data1.RecordSource = "select * from employee_Details order by id"
Data1.Refresh
combo_Sex.Clear
combo_Sex.AddItem "Male"
combo_Sex.AddItem "Female"
End Sub


''''''''''''''''''''''''''''''''''''''''''''''''
'Dito lahat ng pre-defined procedures
''''''''''''''''''''''''''''''''''''''''''''''''

Private Sub clear_all_fields()
txt_Firstname.Text = ""
txt_MI.Text = ""
txt_Lastname.Text = ""
txt_StreetAddress.Text = ""
txt_City.Text = ""
txt_ContactNumber.Text = ""
txt_Birthdate.Text = ""
combo_Sex.Text = ""
txt_Remarks.Text = ""
End Sub
```

```
Tools page
Option Explicit
Dim ans

Private Sub cmd_ClearPicture_Click()
CommDlg_Path.FileName = ""
Img_Emp.Picture = LoadPicture()
End Sub

Private Sub cmd_LoadPicture_Click()
With CommDlg_Path
   .DialogTitle = "Search Employee picture"
   .Filter = "Bitmap (*.bmp)|*.bmp|Jpeg (*.jpg)|*.jpg|Gif (*.gif)|*.gif|All Files (*.*)|*.*"
   .Flags = cdlOFNHideReadOnly + cdlOFNOverwritePrompt + cdlOFNPathMustExist
   .ShowOpen
```

```
    .FilterIndex = 1
    .CancelError = True
Img_Emp.Picture = LoadPicture(.FileName)
End With

End Sub

Private Sub cmdAdd_Click()
Frame1.Enabled = True
Frame2.Enabled = True
txt_NickName.SetFocus
'controls
cmdAdd.Enabled = False
cmdSave.Enabled = True
cmdCancel.Enabled = True
cmd_LoadPicture.Enabled = True
cmd_ClearPicture.Enabled = True


End Sub

Private Sub cmdCancel_Click()
'controls
Frame1.Enabled = False
Frame2.Enabled = False
'controls
cmdAdd.Enabled = True
cmdSave.Enabled = False
cmdCancel.Enabled = False
cmd_LoadPicture.Enabled = False
cmd_ClearPicture.Enabled = False
clear_all_fields
End Sub

Private Sub cmdClose_Click()
Unload Me
End Sub

Private Sub cmdSave_Click()
If txt_NickName = "" Then
    MsgBox "Cannot save if Nickname is empty.", vbExclamation, "Nickname is
missing"
    txt_NickName.SetFocus
    Exit Sub
End If

If txt_FirstName = "" Then
    MsgBox "Cannot save if Firstname is empty,", vbExclamation, "Firstname is
missing"
    txt_FirstName.SetFocus
```

```
    Exit Sub
End If



If txt_Lastname = "" Then
    MsgBox "Cannot save if Lastname is empty.", vbExclamation, "Lastname is missing"
    txt_Lastname.SetFocus
    Exit Sub
End If


If txt_birthday = "" Then
    MsgBox "Cannot save if Birthday is empty.", vbExclamation, "Birth date is missing"
    txt_birthday.SetFocus
    Exit Sub
End If
If IsDate(txt_birthday.Text) = False Then
    MsgBox "Invalid birthdate. Try again.", vbExclamation, "Error birth date"
    txt_birthday.SetFocus
    SendKeys "{home}" & "{end}"
End If



If MsgBox("Confirm add new Item Record.", vbQuestion + vbYesNo) = vbYes Then

    With Data1.Recordset
        .AddNew
            !tool_name = UCase(txt_NickName.Text)
            !Eng_name = txt_FirstName.Text

            !mail = txt_Lastname.Text
            !mintinance_date = txt_birthday.Text
            !note = txt_Remark.Text

            !tool_pic = CommDlg_Path.FileName
            !production_date = Text1.Text
        .Update
    End With
    Data1.Refresh
    MsgBox "Item information save.", vbInformation

End If

clear_all_fields
'controls
cmdAdd.Enabled = True
cmdSave.Enabled = False
cmdCancel.Enabled = True
```

```
cmd_LoadPicture.Enabled = False
cmd_ClearPicture.Enabled = False

End Sub
Private Sub clear_all_fields()
   txt_NickName.Text = ""
   txt_FirstName.Text = ""
   txt_Lastname.Text = ""
   txt_birthday.Text = ""
   txt_Remark.Text = ""

   cmd_ClearPicture_Click
End Sub
Private Sub Form_Load()
Data1.DatabaseName = App.Path & "\CMJ.mdb"
Data1.RecordSource = "select * from Tool_Details"
Data1.Refresh
End Sub



Private Sub Text1_Click()
Dim dtmTest As Date
dtmTest = DateValue(Now)

End Sub
```

Splash page

```
Option Explicit
Dim a As Integer
Dim counter

Private Sub Form_KeyPress(KeyAscii As Integer)
If KeyAscii = 27 Then
   End
End If
End Sub

Private Sub Form_Load()
frmSplash.Width = 8190
frmSplash.Height = 5385
a = 1
counter = 0

Data1.DatabaseName = App.Path & "\CMJ.mdb"
Data1.RecordSource = "select * from Login_Details"
Data1.Refresh
```

```
End Sub

Private Sub Text1_Change()

End Sub

Private Sub Text1_KeyPress(KeyAscii As Integer)

End Sub

Private Sub Timer1_Timer()

Label1.Caption = Label1.Caption & "."
a = a + 1
If a = 7 Then
   Timer1.Enabled = False
   Label1.Visible = False
   txt_Password.Visible = True
   txt_Password.SetFocus
   lbl_EnterPassword.Visible = True
End If
End Sub

Private Sub txt_Password_KeyPress(KeyAscii As Integer)
If KeyAscii = 13 Then
   If UCase(txt_Password) = UCase(txt_dbPassword) Then
      Unload Me
      CMJ_Main.Enabled = True
      'unlock database here
   Else
      MsgBox "Invalid password.", vbExclamation
      txt_Password.SetFocus

      counter = counter + 1
      If counter = 3 Then
         MsgBox "You have reached the maximum tries to enter your password." &
Chr(13) & _
            "System is terminating.", vbExclamation
         End
      End If
   End If
End If
If KeyAscii = 27 Then
   End
End If
End Sub
```

Appendix (III)
(The questionnaire)

جامعة مؤتة

استبيان

حضرة الزميل

تحية طيبة وبعد،

يقوم الباحث بدراسة تهدف إلى الإجابة على التساؤلات التالية :

- مدى اتباع عاملي الصيانة في منجم الأبيض للمعايير الدولية في مايتعلق بإدارة الصيانة .
- مدى فاعلية استخدام الصيانة للحاسب الآلي قياساً للرواد في هذا المجال.
- درجة تطابق ممارسات الصيانة مع أفضل الممارسات وأكثرها فعالية من حيث تكاليف الصيانة والتشغيل.
- مدى تأثير تطبيق معايير الصيانة الدولية واستخدام تقنيات الحاسوب حاليا في تقليل كلفة الصيانة في منجم الأبيض.

وهذه الدراسة جزء من بحث رسالة الماجستير في جامعة مؤتة بعنوان :

نظام إدارة صيانة المعدات الكهربائية والإلكترونية
منجم الوادي الأبيض
شركة مناجم الفوسفات

وقد صمم هذا الإستبيان لجمع المعلومات حول موضوع الدراسة، يرجى منك الإجابة عن فقراتها شاكرين لك تعاونك، ومؤكدين لك بأن المعلومات التي ستقدمها تستخدم للبحث العلمي فقط.

الباحث : هاشم سالم اللوانسة

ملاحظة : يتكون الإستبيان من قسمين هما :

- **القسم الأول :** يتكون من المعلومات العامة ويرجى منك وضع إشارة (X) أمام مايناسب حالتك.
- **القسم الثاني :** يتكون من (53) عبارة لجمع المعلومات حول موضوع الدراسة ويرجى منك وضع إشارة (X) في المستوى الذي يناسبك أمام كل عبارة.

وشكراً لحسن تعاونكم

القسم الأول : المعلومات العامة

1- الدائرة : ( ) الصيانة ( ) التعدين

( ) المستودعات ( ) الإدارية

( ) التصنيع

2- التحصيل العلمي : ( ) بكالوريوس وأعلى ( ) دبلوم

( ) ثانوية عامة ( ) أقل من الثانوية العامة

3- المسمى الوظيفي : ( ) فني ( ) رئيس قسم

( ) مشرف ( ) رئيس شعبة

( ) مساعد مدير ( ) مدير

4- سنوات الخبرة : ( ) أقل من 5 سنوات ( ) بين 5 و 10 سنوات

( ) بين 10 و 15 سنة ( ) بين 15 و 20 سنة

( ) أكثر من 20 سنة

5- العمر : ( ) بين 20 و 30 سنة ( ) بين 30 و 40 سنة

( ) بين 40 و 50 سنة ( ) بين 50 و 60 سنة

القسم الثاني: الفقرات التالية وتتكون من 53 عبارة موزعة على 3 محاور

أولاً : مدى تطبيق ممارسات إدارة عمليات الصيانة وفقا للمعايير الدولية

الرقم التسلسلي	العبارة	موافق جدا	موافق	محايد	غير موافق	غير موافق جدا
1	هنالك جدول زمني دوري لتنظيف وفحص المعدات على شكل صيانة وقائية لرصد اي أعطال كبيرة قد تؤدي إلى توقف تلك المعدات.					
2	كل معدة في مكان العمل لها إجراءات صيانة وقائية حسب توصيات الشركة الصانعة أو المعايير الدولية ويتم التقيد بها في كل مرة بدقة كبيرة.					
3	عادةً يتم إجراء تحليل للأسباب الجذرية للأعطال بعد إجراء عملية الصيانة التصحيحية .					
4	تستخدم أجهزة قياس مثل الحرارة والإهتزاز لتحليل أسباب الأعطال كجزء من سياسة الصيانة التنبؤية.					
5	عقد اجتماعات دورية للوقوف على أهم معيقات تنفيذ أعمال الصيانة.					
6	يتوفر نموذج طلب صيانة في حال حدوث الأعطال مع وصف كامل للعطل .					
7	يتم إصدار تصريح عمل صيانة من قبل أقسام الإنتاج من أجل سلامة العاملين والمعدات.					
8	يتم تسجيل ساعات العمل وقطع الغيار المستخدمة في عمليات الصيانة لحساب تكلفة الصيانة.					
9	هنالك سجل لعدد ووقت الأعطال وتكاليف الصيانة لكل معدة من المعدات المهمة.					
10	تتم جدولة أعمال الصيانة لاستغلال كل ساعات العمل الرسمي لأفراد الصيانة.					
11	يجري إعداد ميزانية سنوية خاصة بالصيانة تحتوي أهم الأعمال والتكاليف المخصصة لها.					
12	هنالك سجل فني لكل معدة مهمة يحتوي على كافة أعمال الصيانة وقطع الغيار المستخدمة والأعطال طوال عمل المعدة.					
13	يتم إجراء أعمال الصيانة بالطريقة الأمثل وبأقل التكاليف الممكنة.					
14	هنالك أشخاص متخصصون في عملية التخطيط والجدولة والتنسيق لأعمال الصيانة.					
15	هنالك سجل لأعمال الصيانة المؤجلة وغير المنفذة.					

الرقم التسلسلي	العبارة	موافق جداً	موافق	محايد	غير موافق	غير موافق جداً
16	يولي أفراد الصيانة عملية النظافة الصناعية بعد إجراء الصيانة أهمية كبيرة.					
17	نسبة قليلة من أعمال الصيانة اليومية هي أعمال طارئة.					
18	يتم تحديد واجبات كل قسم في الصيانة والإنتاج عند أعمال الصيانة المشتركة لمنع التضارب بين الأقسام المختلفة.					
19	يوجد نظام تدريب مستمر لأفراد الصيانة من أجل تطوير مهاراتهم.					
20	هنالك وصف وظيفي يتضمن واجبات كل وظيفة من وظائف الصيانة.					
21	هنالك قائمة مهارات ومتطلبات لكل وظيفة من وظائف أفراد الصيانة.					
22	هنالك نظام لتزويد قطع الغيار وكمية المواد المطلوب تخزينها.					
23	تتم عملية الجرد السنوي لمستودعات قطع الغيار بفعالية.					
24	يتم تخزين قطع الغيار بشكل منظم وبظروف مناسبة.					
25	شراء قطع الغيار لايتم بشكل طارئ.					
26	أماكن العمل في المشاغل والميدان مناسبة من حيث المساحة لأداء أعمال الصيانة .					

ثانياً : فعالية استخدام تكنولوجيا الحاسب الآلي في إدارة عمليات الصيانة بالمقارنة مع الرواد فيهفا المجال

الرقم التسلسلي	العبارة	موافق جدا	موافق	محايد	غير موافق	غير موافق جدا
27	يوجد على الحاسوب سجل لتاريخ معدات المنشأة الفني مثل حفظ وقت الأعطال وأسبابها.					
28	يوجد سجل على الحاسوب لعدد الأشخاص المشتركين بأعمال الصيانة والوقت المستغرق لكل معدة.					
29	قياس مدى إنتاجية العاملين في الصيانة من خلال المعلومات التي يوفرها الحاسوب.					
30	يتم باستخدام الحاسوب حفظ وتوثيق الأسباب الجذرية للأعطال على المعدات للإستفادة منها مستقبلاً.					
31	باستخدام الحاسوب يتم تسجيل وتوثيق قطع الغيار المستخدمة في صيانة كل معدة.					
32	بواسطة الحاسوب يمكن معرفة تكاليف عمليات الصيانة المنفذة.					
33	في حال حدوث عطل يتم إصدار أمر عمل صيانة محوسب ويتم تنفيذ عملية الصيانة بناءً عليه. وأمر عمل الصيانة هذا يحتوي على كل تفاصيل العطل الممكنة.					
34	تنفيذ أعمال الصيانة على المعدات بعد التخطيط والجدولة من خلال الحاسوب لاستغلال الوقت وكل الفعاليات المتاحة.					
35	استخدام الحاسوب لإدارة قطع الغيار في المستودعات.					
36	تمكين فريق الصيانة من معرفة رصيد قطع الغيار بسهولة من خلال الحاسوب.					
37	يتبادل العاملون في مختلف الدوائر البيانات المتعلقة بأعمال الصيانة وقطع الغيار على شبكة حوسبة.					

ثالثاً : مدى فعالية تطبيق ممارسات الصيانة الأفضل والأكثر فعالية من حيث التكاليف

الرقم التسلسلي	العبارة	موافق جدا	موافق	محايد	غير موافق	غير موافق جدا
38	يتوفرالمكان الملائم للعمل من حيث المساحة لتسريع إنجاز أعمال الصيانة.					
39	يتم التحكم بسرعة المحركات الكهربائية حسب الحاجة التشغيلية لتقليل استهلاك الكهرباء .					
40	يتم التحكم بسرعة المحركات الكهربائية حسب الحاجة التشغيلية لإطالة العمر التشغيلي للمحركات.					
41	تستخدم المحركات الكهربائية بالقدرة المناسبة للحمل لضبط تكاليف الشراء و التشغيل.					
42	يتم إيقاف المعدات الكهربائية نهائياً في حالة توقف المنشأة – حسب الظروف التشغيلية - للتقليل من هدر الطاقة .					
43	يتم شراء البدائل الحديثة للمعدات القديمة الأكثرسعراً والتي ربما خرجت من خطوط إنتاج الصانع.					
44	يتم صيانة بعض المعدات رغم أن تكلفة شراء معدة جديدة أقل من صيانتها.					
45	تعتبرالمواصفات الفنية هي الأهم في اتخاذ قرار شراء المعدات وقطع الغيار.					
46	يتم شراء معدات ذات تصميم ومواصفات مناسبة للبيئة التشغيلية لزيادة عمرها التشغيلي وتقليل تكاليف الصيانة.					
47	يتم ترتيب وتنظيم مستودع قطع الغيار من أجل عدم تأخير عمليات الصيانة.					
48	يتم اتخاذ قرار شراء المعدات وقطع الغيار بناءً على السعر.					
49	يوجد أجهزة حماية على المعدات والأقشطة من أجل سلامة العاملين والمعدات.					
50	يوجد أجهزة إنذار ومراقبة في غرف التشغيل لمنع الأعطال قبل وقوعها.					
51	تستخدم أنظمة الإنارة الموفرة للطاقة من أجل استهلاك أقل للكهرباء.					
52	تستخدم تقنية إطفاء الإنارة الخارجية خلال النهار.					
53	تستخدم تقنية إطفاء الإنارة الداخلية للغرف في أوقات عدم إشغالها.					

Appendix (IV)
(The questionnaire arbitrators' names list)

Appendix IV
(The questionnaire arbitrators' names list)

Arbitrator number	Arbitrator name	University
1	Prof Dr. Ayman AL-Momani	Mutah University
2	Prof Dr. Saloom Al-jiburi	Mutah University

المعلومات الشخصية

الاسم: هاشم سالم سليمان اللوانسة

التخصص: ماجستير الإدارة الهندسية

الكلية: الهندسة

السنة: 2016

هاتف رقم: 0779552626